MACHINE DESIGN

THE PROFESSIONAL JOURNAL OF CHIEF ENGINEERS AND DESIGNERS

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This Month's Cover: Power-driven labeling machine automatically applies each label, imprinting it with price, date, code, or other message. Designed by Package Machinery Co., the machine heats the thermoplastic coating of the labels to make them adhesive and seals them to the packages as they pass on a conveyor.

CONTENTS

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Itemized Index

Classified for convenience when studying specific design problems

MACHINE DESIGN is indexed in Industrial Arts Index and Engineering Index Service, both available in libraries generally

NEW G-E SILICONE OILS SPEED TIRE PRODUCTION

How G-E Silicones can help you

Want to speed your production by reducing rejects? Then you'll want to investigate General Electric's new silicones. You'll be amazed at the uses being found for these chemically inert, high-heat-resistant materials.

Look what silicones are doing for rubber tire makers. In this industry, the sticking of tires in molds is a serious problem. But when G-E silicone *oils* and *emulsions* are applied, tires are easily released untorn, unscratched . . . with handsomer appearance than when ordinary release agents are used. Rejects are practically nil. Moreover, G-E silicone oils and emulsions do not build up in molds. Thus down time is reduced . . . production speeded . . . because molds do not need frequent cleaning. There's *money saved,* too, on mold case and tire bag maintenance.

G-E Silicones Have Many Other Uses

In electrical insulation and other applications where extremes of temperature must be overcome in processes or products, manufacturers will find profitable advantages in the use of G-E silicone *resins.* These resins also promise to be extremely useful in compounding long-lasting finishes for automobiles, kitchen ranges and many other products.

WANT TO KNOW MORE ABOUT G-E SILICONES? We'll be glad to go into greater detail with you. Perhaps these amazing materials will solve your particular production problem. Chemical Department, General Electric Company, Pittsfield, Massachusetts.

Please address inquiries about G-E silicones to Resin and Insulation Materials Division, Chemical Department, General Electric Company, Schenectady 5, N. Y.

SILICONES for Industry

GENERAL ELECTRIC

CD48-Q5

Topics

BEADS added to the outer edges of ribs in aluminum castings will facilitate casting as well as reduce the outer fiber stress. If this is not practicable the ribs should be designed with square rather than rounded outer edges.

ALUMINUM bridge to span the Saguenay river in Canada will be the first all-aluminum highway bridge of its type in the world. With an overall length of 504 feet and a main span of 290 feet, it will weigh 400,000 pounds, about half the weight of a similar steel structure. This reduction in weight simplifies foundation work and facilitates erection.

NEW SYNTHETIC rubber, made by the polymerization of butadiene and styrene at much lower temperatures than previously used, will outwear the best natural rubber for tire treads by as much as 30 per cent. The chemical process changes the structure of the synthetic to reduce cracking and increase strength and resistance to abrasion.

RADIOACTIVE TRACERS are being employed in experiments conducted for Republic Steel Corp. to determine the source of sulfur in finished steel. Previous methods could not determine whether the pyritic or organic forms of sulfur in coal were the culprit. Tracers showed both forms to be equally guilty.

MICHELSON Research Laboratory at the United States Navy Ordnance Test Station in the heart of California's Mojave desert is said to be the most complete scientific research facility of its type in the world. It is named in honor of the late Dr. Albert A. Michelson, noted American physicist and Nobel prize winner, and is under the direction of Dr. L. T. E. Thompson.

PRELUBRICANT of synthetic colloidal graphite in alcohol and carbon tetrachloride on friction generating surfaces reduces the surface tension of metal, allowing the surfaces to retain a thicker film of oil. Also the oil spreads 6 to 10 times faster and farther than on untreated surfaces. Besides acting as a wetting agent to distribute the film, the coating acts as a lubricant itself when the regular oil film becomes ruptured.

MICROSCOPIC INSPECTION of crystal structures in cast irons is the subject of a series of reports to be published by the American Foundrymen's Association. It is felt that thorough descriptions of several successful methods will give laboratories data on which to improve their practices.

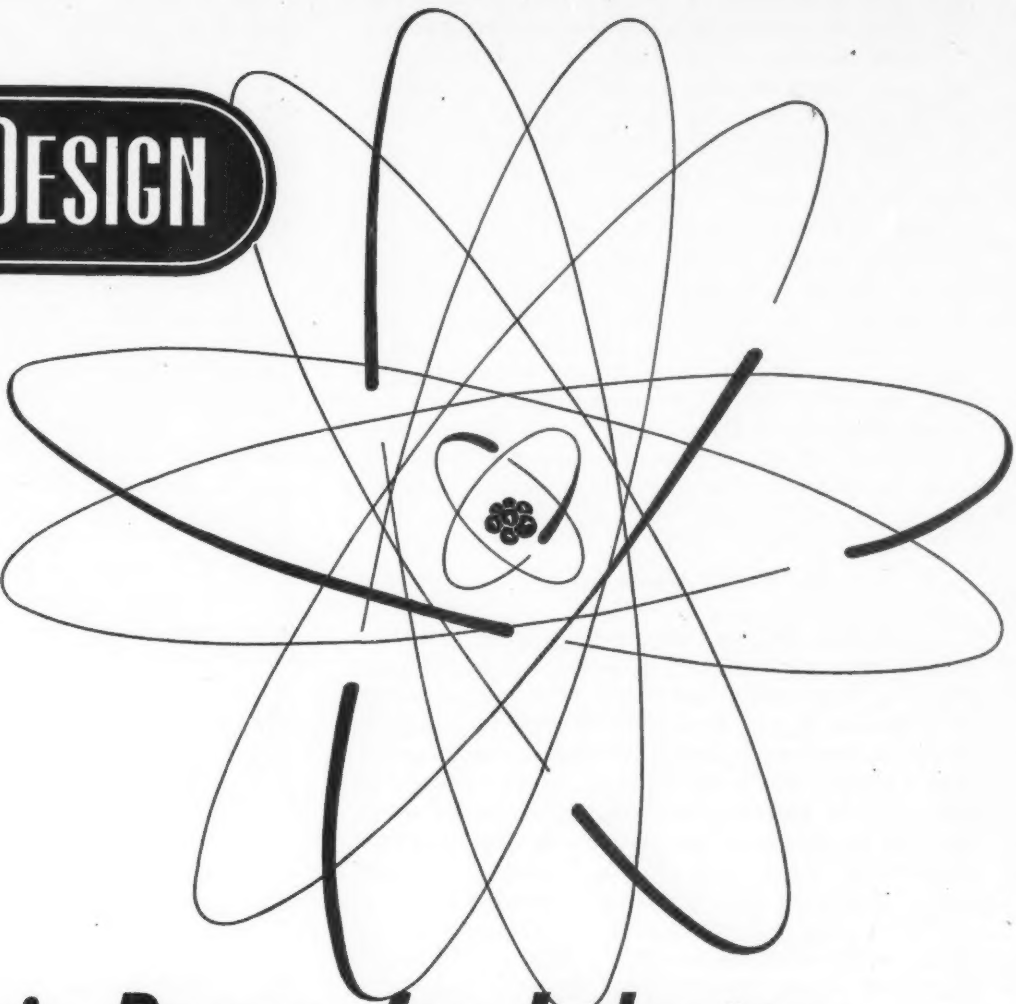
MOLDED NYLON has resiliency and surface smoothness that make it suitable for some bearing and gear applications, outwearing the metals replaced. No lubricant is required for bearings under light load at high speeds or moderate loads at low speeds. When lubricants are necessary either oil or water is used.

ENGINE ANALYZER for diagnosing aircraft engine trouble while the plane is in flight has successfully met performance tests. Inasmuch as 20 to 50 per cent of delays in aircraft operation are due to engine and engine accessory troubles, the analyzer will increase flight utilization of the plane by indicating the exact nature of any trouble while in flight.

MAGNESIUM alloy skin for the fuselage of the new Douglas-built Navy D-558-2 Skyrocket averages 0.1-inch in thickness and does not require longitudinal stiffeners. The thick skin permits use of machine countersunk rivets for a smoother aerodynamic surface.

NATIONAL STANDARDS and measurement methods for radio and electronic equipment include frequency, power, voltage, current, attenuation, impedence, and field intensity. These have reasonably high accuracy and have been developed for frequencies from 10 kilocycles up to 100,000 megacycles.

MACHINE DESIGN



Atomic Power for Industry

Problems of designing equipment to harness nuclear energy for the production of heat and power

By H. Etherington
Director, Power Pile Division
Oak Ridge National Laboratory
(On leave from Allis-Chalmers Mfg. Co.)

NUCLEAR or atomic energy is developed in a reactor* in the form of heat, and it is proposed in this article to indicate some of the engineering problems of extracting and applying the heat usefully and economically. The problems are complex and cannot be discussed adequately without some consideration of the nature of the fission process.

NUCLEAR ENGINEERING OF THE REACTOR: Calculation of a reactor requires a level of mathematics higher than commonly necessary for engineering design. Hitherto, reactors have been calculated by theoretical physicists; but engineering progress in

*"Reactor" has been adopted by the Atomic Energy Commission as a preferred term for a "pile".

peacetime development of atomic energy demands that this work be transferred to the realm of engineering.

Atomic Structure. The atoms of all elements consist of a heavy nucleus surrounded by a planetary system of electrons. The nucleus of the atom is made up of positively charged particles called protons and uncharged particles called neutrons. Protons and neutrons are approximately equal in weight and the total number of protons plus neutrons is roughly equal to the atomic weight of the atom. All atoms of a particular element have the same number of protons in the nucleus, but the number of neutrons can vary over a narrow range. For example, all atoms of uranium have 92 protons in their nuclei, but the two most important kinds of uranium atoms occurring in nature have atomic weights of 235 and 238, reflecting a difference in the number of neutrons in the two types of nucleus. For convenience, these atoms are referred to as U^{235} and U^{238}.

When Atoms Split

The Fission Process. Heavy nuclei tend to be unstable and under sufficient impetus may undergo fission, i.e., may break down into two smaller nuclei. After fission of a nucleus, the two parts remain positively charged and by mutual repulsion acquire a very high velocity (about one thirtieth of the velocity of light). The particles are stopped by surrounding solid or liquid matter in considerably less than one thousandth of an inch of travel, and the kinetic energy of the particles is converted into heat.

Critical Mass. There is only one naturally occurring, readily fissionable material. This is U^{235} which is present in the amount of 0.7 per cent in natural uranium, the balance being almost entirely U^{238}. When fission occurs in U^{235}, in addition to the two major fragments, some surplus neutrons appear as debris from the disintegration. The neutrons are emitted at high speed, approximately one fifteenth of the speed of light, and nuclear engineering is concerned largely with the fate of these neutrons. On the average, one to three neutrons per fission are emitted. The actual number is of course known, but the information is secret and in order to make the ensuing discussion more concrete we shall assume that there are two neutrons released for each fission of U^{235}.

If the planetary system of a single atom be represented by a circle 12 inches in radius, and a barely visible dot be made at the center with a hard pencil, this dot might represent to scale the size of the nucleus of the atom. A neutron is somewhat smaller still. An individual nucleus, therefore, presents an exceedingly small geometric target and neutrons can wander through matter with considerable freedom, so that many of them escape from a reactor and are lost completely. In a reactor containing only a few atoms of U^{235}, the total effective target area presented by the U^{235} nuclei would be so small that if a fission occurred within the reactor most of the two neutrons would escape and no chain reaction could occur. If the U^{235} is increased until the total effective target area is such that there will be one fission hit for each fission occurring, then a self-sustaining "chain reaction" will result and the weight of U^{235} is called the critical mass for the particular reactor.

Conversion of Available Materials

Nuclear Fuels. Although U^{235} is the only naturally occurring easily fissionable material, both of the practically nonfissionable nuclei, U^{238} and Th^{232} (thorium of atomic weight 232) can absorb one neutron per nucleus and, after two subsequent spontaneous nuclear changes, become the new easily fissionable nuclei

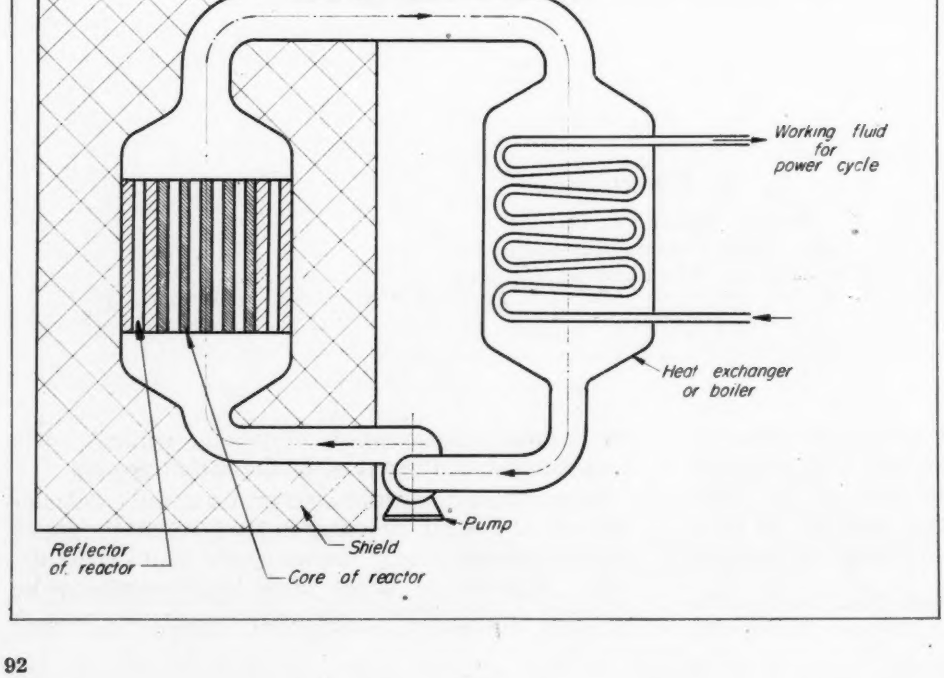


Fig. 1—Schematic arrangement of an atomic power plant. The working fluid may be steam or gas for use in a conventional turbine or other form of engine

Pu^{239} (plutonium of atomic weight 239) and U^{233} (uranium of atomic weight 233) respectively. Neither of these materials occurs naturally on earth. Of the two neutrons assumed to be obtained from fission of a U^{235} nucleus, one is needed to continue the chain reaction and the other one is, under ideal conditions, available to convert a nucleus of U^{238} or thorium into a new fissionable atom. Industrial power reactors must be designed to secure advantageous use of this available neutron. In fact, conversion is so important that the whole future of large scale atomic energy may well depend on the degree of conversion attainable, the optimum condition being production of at least one new fissionable atom for each atom consumed in the reactor, and so eventually to make available for fission the relatively large resources of thorium and U^{238}.

The presently known nuclear fuels are thus U^{235}, Pu^{239} and U^{233}. The first of these is present in natural uranium and *can* be used without separation from the associated U^{238}. However, direct use of natural uranium does not permit good neutron economy, and in general will require a considerably larger reactor and bigger critical mass than for the concentrated fuels.

Uranium enriched in U^{235} is being produced at the \$500,000,000 separation plant at Oak Ridge, and when military conditions permit, it is presumed that this material will become available as initial charge material for industrial plants. It is probable that such plants may then have to generate fuel for continued operation from the cheaper and more abundant materials, natural uranium and thorium. Plutonium is being produced in the large Hanford plants and it is hoped that it will become available ultimately for use in the same way as U^{235}. The third fuel, U^{233}, exists only in quantities sufficient for laboratory investigation and will not be commercially available until large scale reactor operations have permitted manufacture of this fuel.

Fast and Thermal Reactors. If the fast neutrons from fission are permitted to bounce around in a mass of atoms at ordinary temperatures they will impart their excess kinetic energy to the atoms by collision and may ultimately be slowed from their initial velocity of about 12,000 miles per second to a velocity of about 1.4 miles per second, at which they will be in equilibrium with molecular and atomic movement at ordinary temperatures. A fast reactor is one in which the chain reaction is sustained by neutrons that retain much of their initial velocity, whereas in a thermal reactor fission is produced by neutrons that have been slowed approximately to thermal velocities.

Thermal Reactor Favored

At thermal neutron velocities, the effective target area of fissionable nuclei is increased several hundred times; consequently the critical mass of fissionable material can be much smaller for a thermal reactor than for a reactor operating on fast neutrons. This decrease in inventory of a very expensive and scarce material strongly favors adoption of a thermal reactor for industrial purposes. Heat transfer considerations lead independently to the same selection.

The Moderator. The material employed to slow the fast neutrons is called a moderator. Moderators must be chosen from among the elements of low atomic weight and their compounds. If atomic weight were the only criterion the most effective moderators would be hydrogen, heavy hydrogen, helium, lithium, beryllium, boron, carbon, etc., in the order named. However, other considerations eliminate helium, lith-

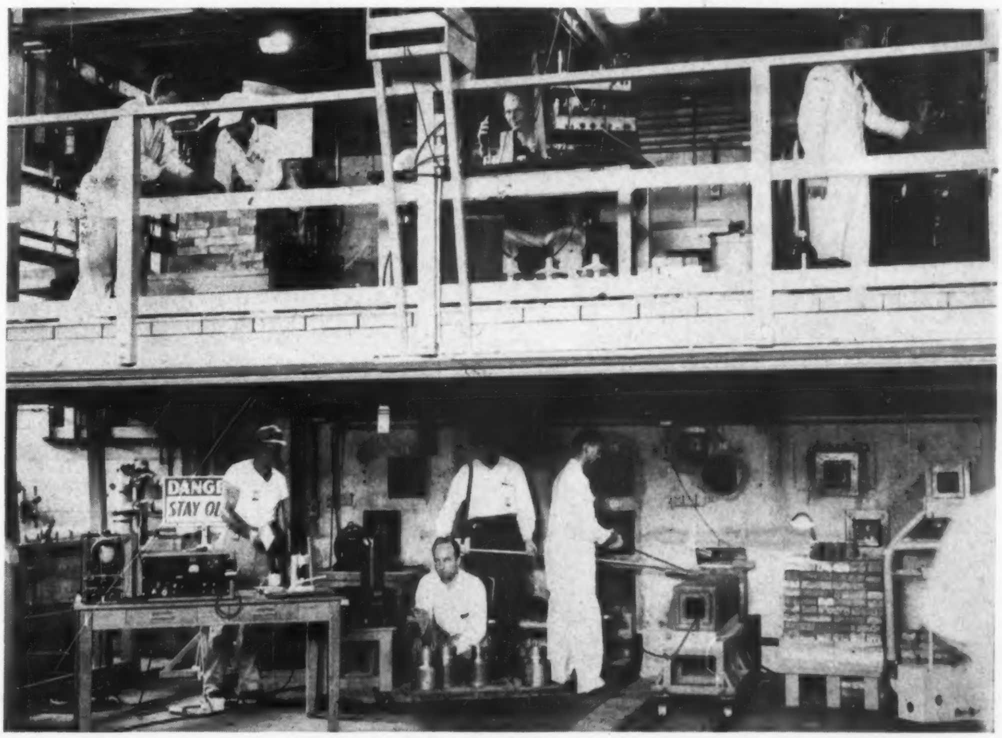


Fig. 2—One face of the Oak Ridge reactor. This face shows plugged holes used for experimental purposes. Personnel are protected by thick concrete radiation shield

ium and boron; so we are left with hydrogen, heavy hydrogen, beryllium and carbon or their compounds as the only promising moderators.

THE PROBLEMS OF DESIGNING THE FIRST POWER REACTOR. *Fig.* 1 shows diagrammatically the basic features of a promising type of atomic power plant. The reactor is constructed of moderating material pierced by a large number of parallel holes. Fissionable material is inserted in the core or center part of the reactor. The core is surrounded by a reflector, probably of the same material as the core and of similar construction. This reflector is the breeding ground for manufacture of new fissionable material from thorium or from U^{238} placed in the holes of the reflector. Neutrons leaking from the core into the reflector have their direction changed by collision with atoms of the reflector and many get turned around and re-enter the core, thus permitting a decrease in the critical mass. Other neutrons that would otherwise escape become absorbed in thorium or U^{238} and so promote neutron economy.

Possible Working Fluids for Power Cycle

Heat received by the recirculated coolant or heat exchange medium is transferred in a heat exchanger to the working fluid for the power cycle. The working fluid may be steam used in a conventional steam turbine plant, air or gas for use in a gas turbine cycle, or any other fluid that can suitably be used in any form of heat engine.

At the present time it is not possible to exclude any type of reactor from consideration. There are many difficult selections to be made and it may be necessary to build several power reactors before the ultimate trend of industrial atomic power plant practice becomes clearly established.

The Kind of Reactor. Much heat exchange surface and reactor bulk is necessary for extraction of the large quantity of heat to be developed in a power reactor. A thermal reactor already provides this bulk in the necessary moderator, wherein it differs from a fast reactor. It has been explained moreover that a thermal reactor has a much lower critical mass of fissionable material than a fast reactor. The thermal reactor therefore offers a promising line of development for atomic power plants.

The natural uranium, graphite-moderated reactors built during the war are very large (*Figs.* 2 and 3), and therefore provide the bulk favorable to high power output. However, they are expensive to build and, as has been stated, natural uranium does not provide the good neutron economy desired for making new fissionable material.

Present indications, therefore, appear to favor a thermal reactor operating on enriched U^{235} with subsequent substitution of U^{233} as the reactor breeds this fuel from thorium.

Choice of Materials for Use in Thermal Reactors. In addition to the moderator, the reactor may have to contain other constructional materials. The operating conditions in a power reactor severely restrict the choice of constructional materials. In varying degree the nuclei of all atoms absorb neutrons; and except where this absorption results in fission or conversion of a nonfissionable nucleus to one that is fissionable, this represents a parasitic loss of neutrons.

Neutron economy prohibits extensive use of any of the common metals within the reactor. Some use of aluminum is permissible and minor parts of iron and the other common metals can be tolerated.

Some elements such as boron have such an enor-

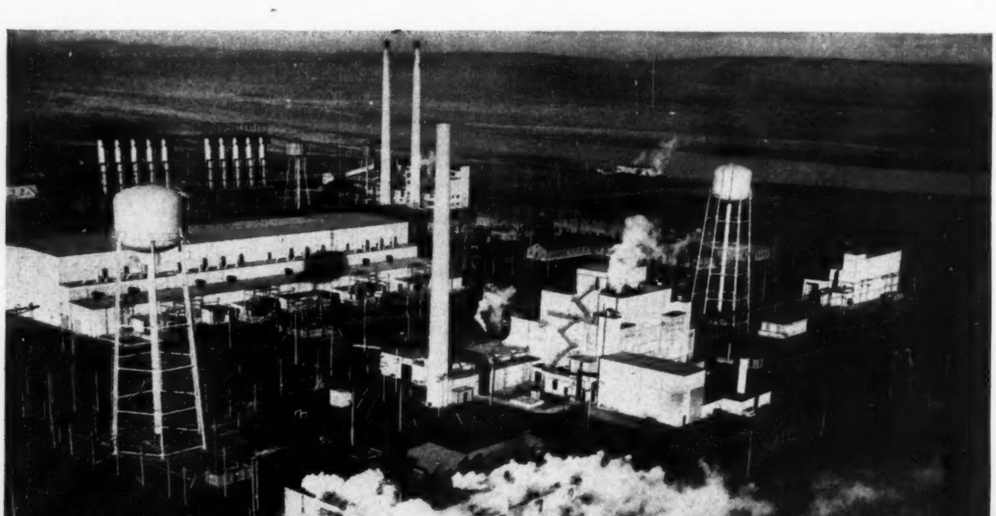


Fig. 3—One of the production areas at the Hanford Engineer Works near Pasco, Washington

mous affinity for neutrons that they can be tolerated only in traces, and exceptional purity is demanded in all reactor materials which are used in considerable quantity.

After preliminary selection of materials in accordance with nuclear requirements it becomes necessary to consider fabrication and procurement problems and to satisfy normal engineering requirements. Obviously the material must be sufficiently strong at the temperature of operation and must be chemically inert to the coolant and other materials in contact with it. The very high heat release in a relatively small volume of material makes it necessary to pay particular attention to material properties and designs conducive to low thermal stress.

Application of materials to new fields has in many cases yielded unexpectedly disappointing results. In a reactor the conditions of service will be radically different from those in any tried and proved application, and cautious exploratory work will be necessary before *any* material can be used with entire confidence.

Radioactivity. When a nucleus absorbs a neutron or undergoes some other type of change, the nucleus commonly finds itself with surplus energy over its "ground state"—it is said to be in an excited state. The excess energy is usually dissipated by emission of one or more gamma rays, identical in character with very high energy X-rays.

Instability of Reactor Products

The nuclear changes occurring within the reactor give rise to unstable nuclei that, like radium, undergo radioactive decay extending over an indefinitely long time. Consequently, not only is there intense radioactivity directly associated with neutron absorption while the reactor is in operation, but there is also continuous emission of gamma rays at a gradually declining rate for some time, even after the reactor is shut down.

Nuclear reactions also give rise to alpha particles, which are essentially high velocity helium nuclei, and beta particles which are high velocity electrons.

Shielding of reactors to protect personnel from the effects of radiation is of course of paramount importance. Shielding from alpha and beta rays is easy because these charged particles are stopped in a small fraction of an inch of travel in solid matter. Gamma rays and X-rays must be reduced to a safe level by heavy shielding just as in industrial radiographic work. Slow neutrons may be absorbed in human tissue with production of gamma rays, and fast neutrons may cause even more extensive damage when they impinge on atoms in the tissue. Such effects are taking place continually in the human body under the influence of cosmic rays and some increase in this normal condition is tolerable. Tolerance standards and methods of measurement have been established and the shielding design must assure that exposure will be well below the tolerance level which experience has shown to be safe.

The shielding must contain sufficient neutron absorbing elements; it must contain light elements to slow down the fast neutrons so that they can be more readily absorbed; and it must absorb gamma rays, which can be best accomplished by heavy elements but which can also be accomplished by a sufficient thickness of light elements. Ordinary concrete provides a cheap but bulky compromise of conflicting requirements. The word "cheap" is relative only, since reactors may be large and the concrete must be several feet thick.

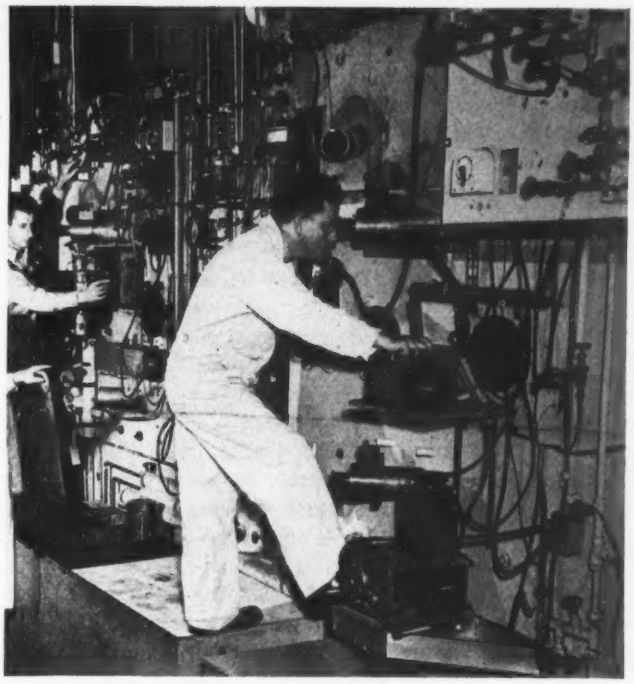


Fig. 4—Remote control and viewing equipment for small-scale process work conducted inside a concrete cubicle

Heat Exchange Medium. The more obvious heat exchange mediums include air and other gases, water and liquid metals. Liquids are inherently superior to gases in that they require less pumping power for a comparable rate of heat removal.

Disadvantages of Water for Heat Exchange

Water is excellent as a *coolant* and is used to cool the large plutonium producing reactors at Hanford, Washington (*Fig.* 3). However, water is far from ideal as a *heat exchange medium* for production of power, because the system must be operated at extremely high pressure to produce heat at a thermodynamically desirable level. Use of water presents the additonal problem of finding materials, acceptable from a nuclear standpoint, that will resist corrosion at elevated temperatures and that will not develop films detrimental to heat transfer.

Choice of liquid heat exchange mediums other than water appears to be restricted to those low melting metals and alloys that have suitably low neutron absorbing characteristics. Obviously the use of liquid metal at high temperatures will pose serious metallurgical problems.

Air is used as the coolant in the reactor (*Fig.* 2) operated at Oak Ridge National Laboratory, Tennessee (formerly Clinton Laboratories) for produc-

tion of radio-isotopes and for experimental purposes. The heated air is discharged through a stack with no attempt at heat recovery. The reactor to be completed next year at Brookhaven National Laboratory, Long Island, will also be air cooled and heat will be recovered from the air to generate electric power as a by-product. The temperature level will, however, be much lower than desirable for a true power reactor—at really high temperatures, graphite would burn and aluminum metal parts, if used in the reactor, would oxidize.

Inert gas as a heat exchange medium may well solve the problems of chemical and metallurgical attack—in fact, helium was originally considered as the coolant for the Hanford reactors. However, to keep the pumping power within reason it will be necessary, as in the case of water, to operate the system under pressure. Gases alone appear to hold promise of attaining really high temperatures, such as would be required for gas turbine plants or for high temperature process work. It can only be said at this time that the choice of coolant is controversial.

Fuel Canning. The uranium slugs used in the Oak Ridge and Hanford reactors are encased (canned) in aluminum jackets. The reason is two-fold. Firstly, uranium metal is highly active chemically and is oxidized by air and corroded by water. Secondly, the intensely radioactive fission products must not be permitted to enter and contaminate a coolant that is being continuously discharged. Development of adequate canning methods at Hanford was a very difficult problem because the container must be gas tight and must permit uniform cooling of the uranium slug at all parts.

Materials Problems in Fuel Canning

Even for a coolant flowing in closed circuit, canning is at least highly desirable. For high temperature application it is necessary to solve the metallurgical and chemical problems of undesired alloying and diffusion, the fabrication problems of canning complex shapes required for good heat transfer, and the usual high temperature operating problems of warpage and plastic deformation.

Chemical Problems. During operation the uranium and thorium slugs undergo nuclear and physical changes which make it necessary to withdraw them periodically for chemical reprocessing and refabrication. The extraordinary radioactivity of the slugs requires that chemical reprocessing be done by remote control in heavily shielded equipment. *Figs.* 4 and 5 illustrate this type of operation on a laboratory scale.

Mechanical Problems. The fundamentally simple system indicated in *Fig.* 1 involves some difficult mechanical problems. The reactor structure must provide for positive and permanent alignment of fuel channels and mechanisms must be provided for selective insertion and removal of fissionable material and thorium. Material handling must be accomplished through a heavy shield and the handling machinery must cause no local interruption in the efficacy of the shield.

The system may have to operate under high pressure, and at least much of it will be heavily shielded. Valves, seals, and blowers or pumps must confine a coolant that may become highly radioactive and those components themselves may become radioactive. Outward leakage to the surroundings must be virtually zero, and many systems that are considered commercially tight for handling ordinary fluids would fail to meet the requirements of an atomic power plant. Moreover, many of the common gasket materials and lubricants would break down under irradiation such as might occur in the system. All equipment that might require inspection or servicing must be so designed that decontamination with acids and other solvents can be accomplished, and in some cases it may be necessary to provide for the replacement and maintenance of equipment by some system of remote control.

Control and Instrumentation. Control of the reactor requires very careful mathematical study. To

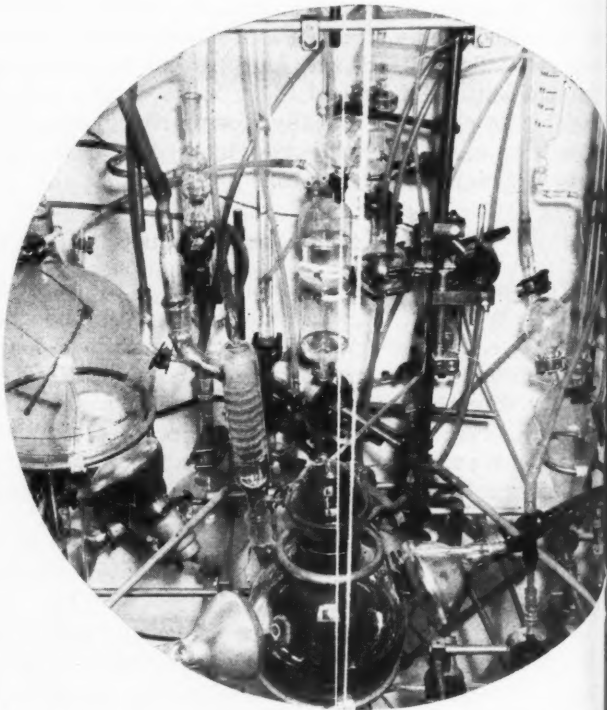


Fig. 5—Process equipment viewed through one of the special periscopes shown in Fig. 4

permit control, a reactor must have more than the theoretically exact critical mass of fissionable material, and the excess over criticality is neutralized by insertion of control rods that contain nuclear "poisons", i.e. materials having a very high neutron absorbing capacity, such as cadmium or boron. When the control rods are inserted to a distance that leaves the reactor exactly critical the reactor will continue to develop power at a constant rate, whatever that rate may be. If the control rods are withdrawn slightly the reactor will be super-critical, and the power output tends to increase rapidly and continuously. To increase the power output in accordance with the demand the control rods are withdrawn

slowly, causing the power level to increase and when the power reaches the desired level the rods are reinserted sufficiently to hold the reactor at criticality. Obviously the control must be very positive in its action and the electrical and mechanical design must provide full automatic operation and must be heavily biased in the direction of safety.

Existence of eight reactors has been acknowledged. The control problem has been solved for these, and there can be no doubt that it will be solved for future reactors, including power reactors.

THE FUTURE OF ATOMIC POWER. There can be little doubt that atomic energy will ultimately play a major part in industry, but it is too early to predict with assurance how soon or under what conditions it can compete with other, well established, sources of power.

Economics of Atomic Energy. Fission of one pound of material produces as much heat as combustion of 1500 tons of coal, which at $7.00 per ton would cost about $10,000. Since recent price quotations of uranium and thorium in chemical combination are only about $3 and $4 per pound respectively, it is entirely possible, in spite of costly processing, that nuclear fuel may prove to be a negligible item in the cost of atomic power.

On the other hand, the investment costs of the power plant will be greatly increased by addition of the reactor. It has been estimated (Reference 2) that a complete nuclear power plant employing a modified Hanford type of reactor would cost about two and one-half times as much as a coal power plant, and that on this basis, the nuclear plant would be competitive if coal costs $10.00 per ton. However, the Hanford reactor was considered in that study chiefly because design and operating data were available for this type of reactor. A reactor design primarily for power production may be expected to present a more favorable picture than a modification of a reactor designed for another purpose.

Initial Fields of Application

Probably nuclear power will find its first competitive application where transportation adds greatly to the cost of conventional fuels. Such applications include marine propulsion to increase the payload by eliminating bunker fuel, and power installations in regions remote from fuel supplies.

Another promising application for nuclear energy is production of very high temperatures. The temperature attainable in a reactor is limited only by the refractoriness of the constructional materials used, so that it is possible to attain, direct, temperatures now requiring expensive electric heating. Technological difficulties suggest, however, that high temperature production must await successful development in the intermediate temperature range of the nuclear power plant.

How Soon Could a Nuclear Power Plant be Built? Mention has been made of the expected production of by-product power from the Brookhaven National Laboratory reactor in 1949. This incidental production of power may not be a significant step in development of nuclear power, and the reactor probably should not be considered as a power reactor in the accepted sense.

With the urgency that characterized the project during the war, and with a small fraction of the war-time effort, there is little doubt that experimental high-temperature power reactors could be built within two years to produce a few thousand KW of electrical output, and that early development of large power reactors could be forced. In this country there appears to be no need for this degree of urgency. However, in other countries, geographic and economic conditions may well point to a greater urgency; and it need hardly be pointed out that an extensively developed unpoliced atomic power industry presents an enormous military threat.

The expensive high-purity materials necessary in a reactor, the elaborate control system to insure safe operation, and the very extensive shielding to protect personnel against radiation all contribute to make a reactor an extremely expensive unit. The requirements are similar whether the reactor is developed for small or large power output, and even an experimental reactor with its appurtenances will cost several millions of dollars.

Other Claims to Effort and Expenditure

The effort and expenditure that can be allocated to a development and construction program for experimental atomic power plants at this time must be weighed against military demands and the demands for expanded experimental scientific work.* These difficult decisions must be made by the Atomic Energy Commission, and unofficial speculation concerning the rate of atomic energy development should be given little weight.

CONCLUSION: Continuing research is paving the way to successful development of an atomic power industry by expanding our knowledge of reactor characteristics, by developing suitable materials and by contributing to the solution of many other problems. The engineering problems are neither trivial nor insuperable; they must be solved by engineering development proceeding concurrently with research. Components must of course be designed and tested but experimental reactors must also be built and operated before commercial atomic power can become a reality. The engineering development probably will take many years and a concentrated major effort must not too long await further study of fundamental problems.

ACKNOWLEDGMENT: This article is based on work performed under contract Number W-35-058-eng-71 for the Atomic Energy Project at Oak Ridge National Laboratory.

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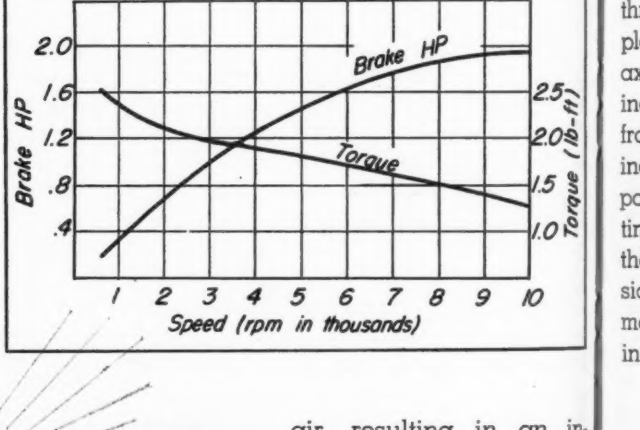
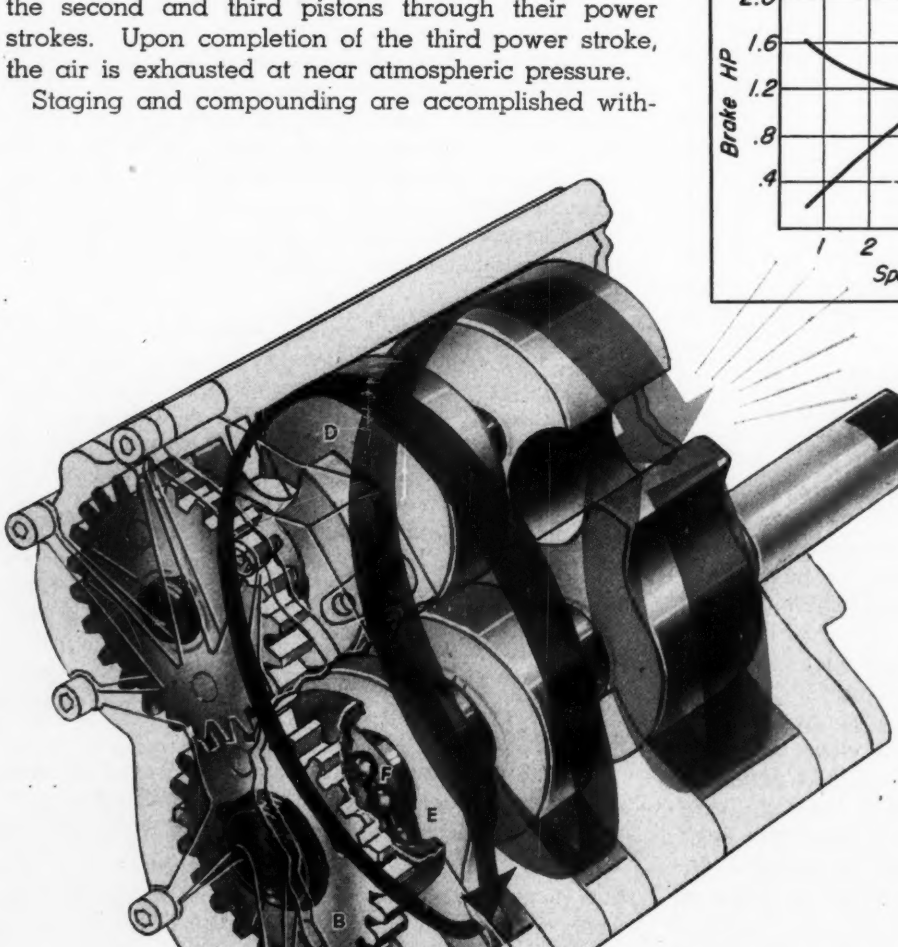
Scanning THE FIELD *for Ideas*

Pneumatic motor illustrated in sectional view below utilizes positive displacement rotary pistons. Designed by Berry Motors Inc. to employ the multiple-expansion principle, it has three thermodynamically balanced stages. Compressed air enters the first stage at receiver tank pressure, drives the piston in this cylinder through its power stroke, passes to the next cylinder, continues to expand, and successively drives the second and third pistons through their power strokes. Upon completion of the third power stroke, the air is exhausted at near atmospheric pressure.

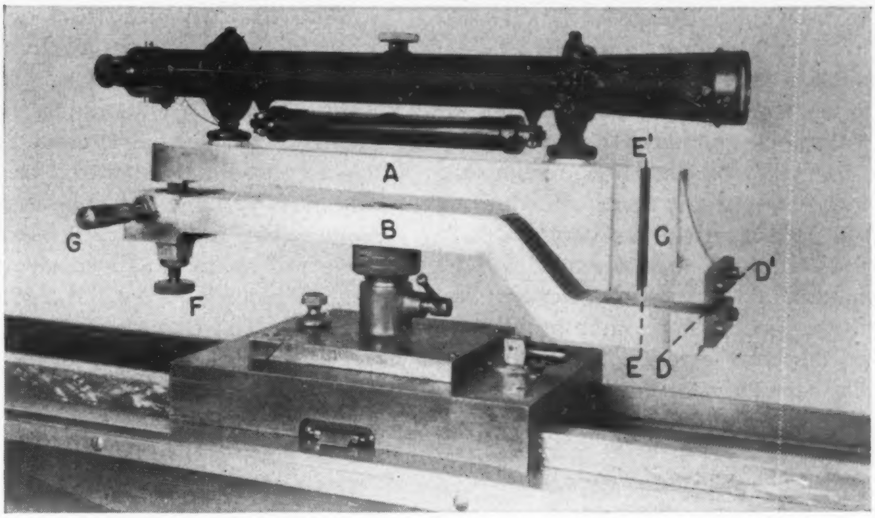
Staging and compounding are accomplished without the use of valving, the pistons offering the only resistance to the continuous flow of air. By this method of compounding, force is obtained from both the expansion and the velocity of the air, resulting in an increase in torque at all speeds. To further increase torque at low speeds an adjustable bypass valve is provided between the inlet and second stages. This valve is arranged so as to permit the flow of high pressure air from the inlet to the second stage as load conditions require.





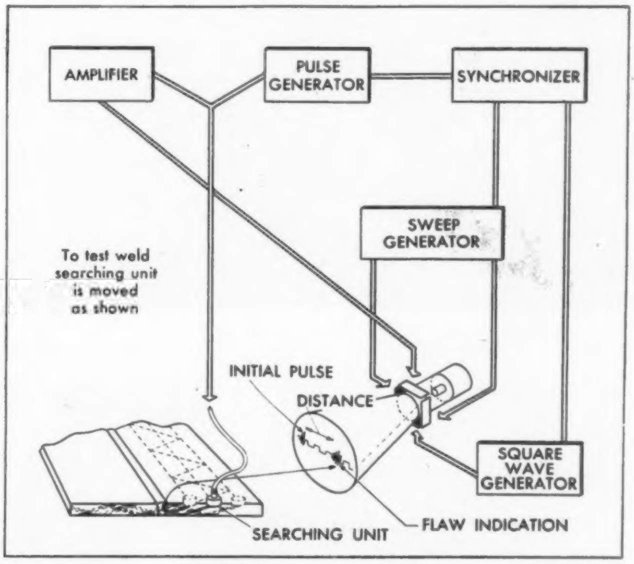
In the sectional drawing (A) is a band showing flow of air through the three compounded stages, (B) timing gears, (C) inlet, (D) abutment valve, (E) pistons, and (F) bearings. Torque and horsepower characteristics of this ¾-horsepower motor are plotted against speed in the curves above.

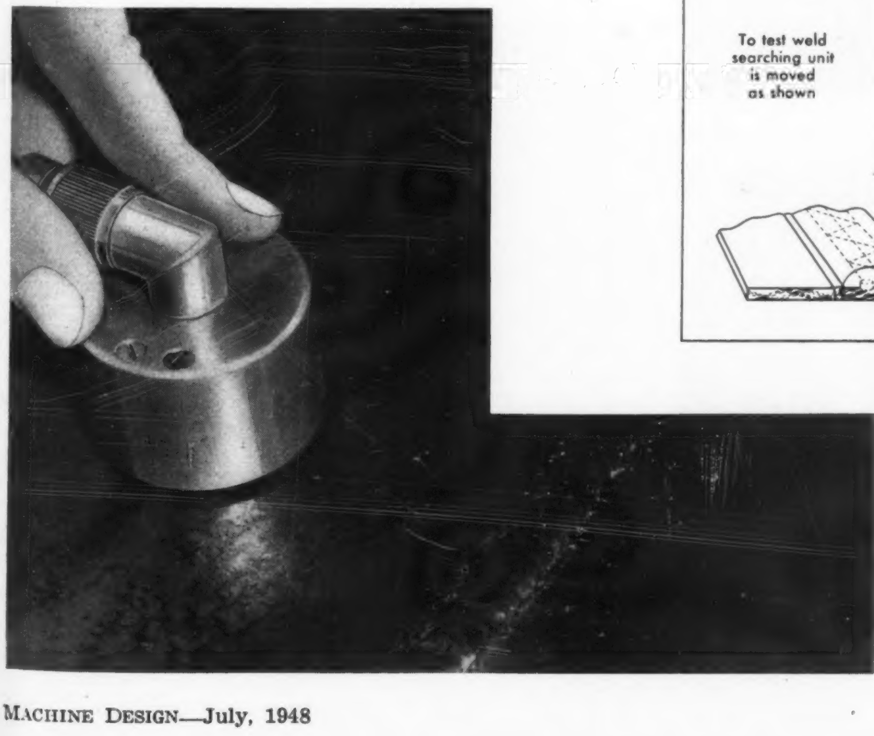
Flexure plates form the mounting of the telescope at right in order to provide precise adjustment of angular movements about two perpendicular axes. Generally, a pair of trunnions and bearings are employed to accomplish such movement. This ingenious design by F. A. Case at the National Bureau of Standards has many advantages. Difference in cost between flexure plates and trunnions is largely in favor of the plates. Also lost motion will never develop. The ease of movement facilitates making of fine settings and the elimination of clamps is desirable for convenience of operation and prevention of drift. Flexure plates, being near the objective end of the telescope, greatly reduce the lateral shift of the entrance pupil when the telescope is rotated.



The telescope is rigidly attached to a dural casting (A) while a similar piece (B) is rigidly mounted. These are flexibly connected through a third dural casting (C) by two phosphor bronze flexure plates, permitting rotation about the horizontal axis DD′ and vertical axis EE′. Direct adjustments to 0.001-inch and by vernier to 0.0001-inch is provided at the eye end of the telescope. Since the radius from the flexure plate to the micrometer head is approximately 15 inches, 0.001-inch corresponds to about 15 seconds. A spring box opposes the micrometer head and maintains any setting. By designing clamps for the flexure plates so that the portion free to bend is short, the compressional stresses are accommodated without impairment of performance. Each flexure plate is 2½ inches wide to restrict motion to the desired plane.

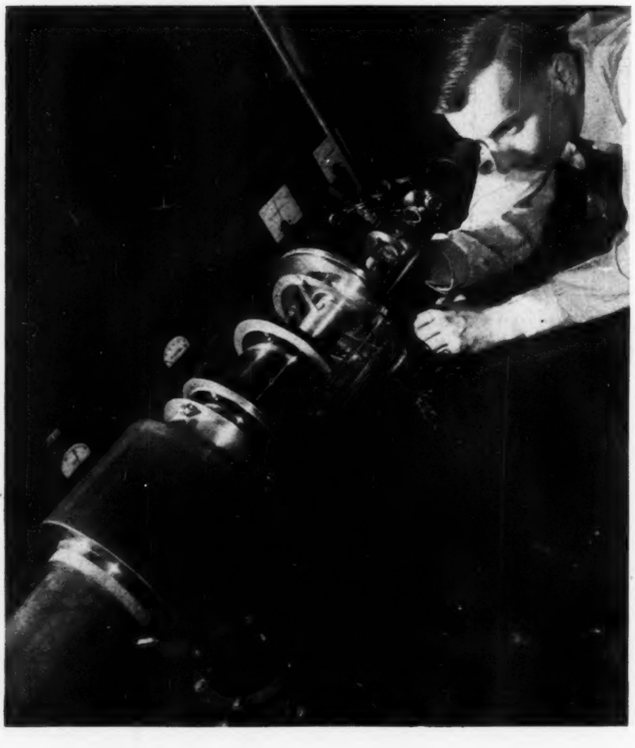
Supersonic testing of welds in ferrous and light metals with the Reflectoscope illustrated at left below detects lack of bond, inclusions or voids. Developed by Sperry Products Inc. the method is known as angle beam transmission and makes possible the entrance of the sound beam into the welded part at an angle. A schematic diagram of the system is shown above. The searching unit, whose primary element is a quartz crystal, can be placed on the smooth parent metal adjacent





to the weld or even at some distance from it. The energy travels by successive reflections between the surfaces of the material until an interface is reached. The weld metal itself will not constitute a reflecting interface but any voids or inclusions will reflect part of the beam back to the searching unit where it will be amplified to provide a vertical deflection of the horizontal trace on an oscilloscope screen. By controlling the sensitivity of the instrument, defects or voids too small to affect the efficiency of a weld can be bypassed, facilitating inspection.

Actual amplification of an X-ray image with a new tube increases the brightness of fluoroscopic images by 500 times. The amplifier, shown at left and the result of four years of intensive study at the Westinghouse Research Laboratories, consists of a high-vacuum tube that electrostatically focuses and accelerates an electron stream. Increased brightness of the X-ray image has been attained by converting the X-ray quanta into light with a fluorescent screen and thence to electrons by means of an adjacent photoelectric surface. These electrons are accelerated by a high potential placed across the vacuum tube, giving a brightness gain of 20 times. A further factor of 25 in brightness gain is attained by electrostatic focusing of the electron stream to reduce the image to 1/5 its size. The reduced image, brightened 500 times, impinges on a phosphor output layer that converts it back to a visible image. This visible image is observed through a conventional optical system that magnifies it by a factor of 5 back to its initial size without losing the brightness gained in the reduction. A schematic drawing of the tube is shown.



Brightness of the fluoroscopic image is amplified after the X-rays have passed through the patient. This approach is considered necessary because the X-ray intensities are already at the patient's tolerance level and the physician's eyes are not sufficiently sensitive to always diagnose adequately the low brightness of a direct image on a fluorescent screen.

Radioactive isotope, by-product of atomic energy plants, is the heart of a new gage for measuring the thickness of thin films. Developed by W. E. Morris, research physicist at the Goodyear Research Laboratory, shown measuring the thickness of a sheet of Pliofilm below, the gage uses a radioactive form of carbon known as Carbon 14. At present the gage will read to an accuracy of a hundred-thousandth of an inch and it is expected that further refinements will effect an accuracy of a millionth of an inch. No mechanical contact with the film is required, facilitating the accurate measurement of soft materials.

Film to be measured passes through a slot in the gage. Below this slot is a small amount of Carbon 14 and above the slot is an ionization chamber in which is produced a minute electrical current by the rays transmitted through the film. The number of electrons getting through the sheet is proportional to its thickness. The produced current is amplified by subminiature vacuum tubes to the point where it is sufficiently large to operate a meter, indicating the strength of the rays and the thickness of the material. Further amplification could be used to actually control the film gage by regulation of the speed of the production machinery.

Carbon 14 is one of the weakest of the radioactive isotopes and, for all ordinary purposes can be regarded as harmless. It gives off only a weak stream of beta rays which are electrons like those released by the filament of an ordinary radio tube.

Gyroscopes and Their Applications

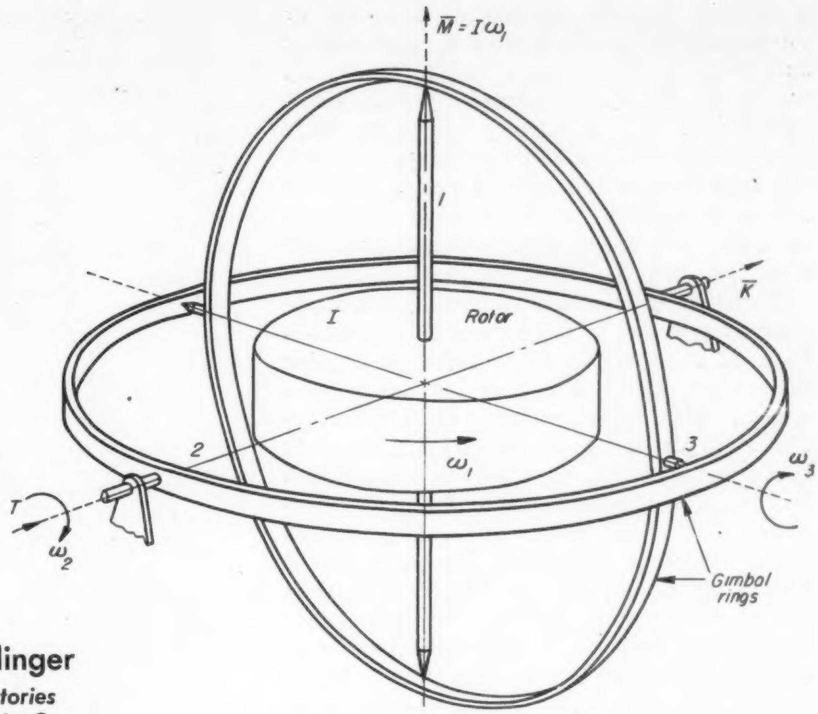


Fig. 1—Above—Torque required to turn axis No. 2 when rotor is spinning is much greater than when the rotor is stationary; this is rigidity. Torque applied to axis No. 2 causes rotation about axis No. 3; this is precession

By K. A. Oplinger
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GYROSCOPES do not appear to obey the generally known principles of force and reaction. Force applied to a gyroscope results in motion at right angles to the plane of the applied force. At first glance a gyroscope appears to be simply a spinning mass and, if an attempt is made to determine reactions about three axes moving simultaneously, a complete general analysis leads into advanced principles of dynamics and mathematics. Fortunately, motion of most gyroscopes in practical applications can be understood without making a complete analysis of a freely spinning mass.

Basic Principles of the Gyroscope: By rolling his hoop, a boy gives it angular momentum so that it resists forces trying to change its plane of rotation. This resistance is referred to as "rigidity in space". Ability to maintain a fixed plane of rotation is one of the fundamental properties of the gyroscope. Although any mass in motion tries to maintain its direction in space, this effect is more pronounced in a spinning mass or gyroscope because, by making the angular velocity high, a large angular momentum can be given a body having a relatively low moment of inertia.

Fig. 2—Below—Weight of the gyroscope causes a torque about an axis at right angles to the spin axis. This results in precessional motion about an axis at right angles to both

What Causes Precession

Also, the boy with the hoop unconsciously applies a second fundamental principle of the gyroscope—precession. If he touches the side of the rolling hoop lightly at the top he easily changes its direction of travel. This change, precessional motion, results from application of a small torque about a horizontal axis at right angles to the spin axis, causing the hoop to precess or turn about a vertical axis perpendicular to both spin and torque axes.

These two basic principles are more apparent if observed on a free or neutral gyroscope supported in gimbal rings as shown schematically in *Fig.* 1. If an attempt is made to rotate spin axis No. 1 rapidly about either of the horizontal axes the spinning rotor resists angular displacement with a relative high reaction torque. This torque tends to hold the spin axis fixed in space with respect to angular displacement but does not oppose linear motion of the gyroscope.

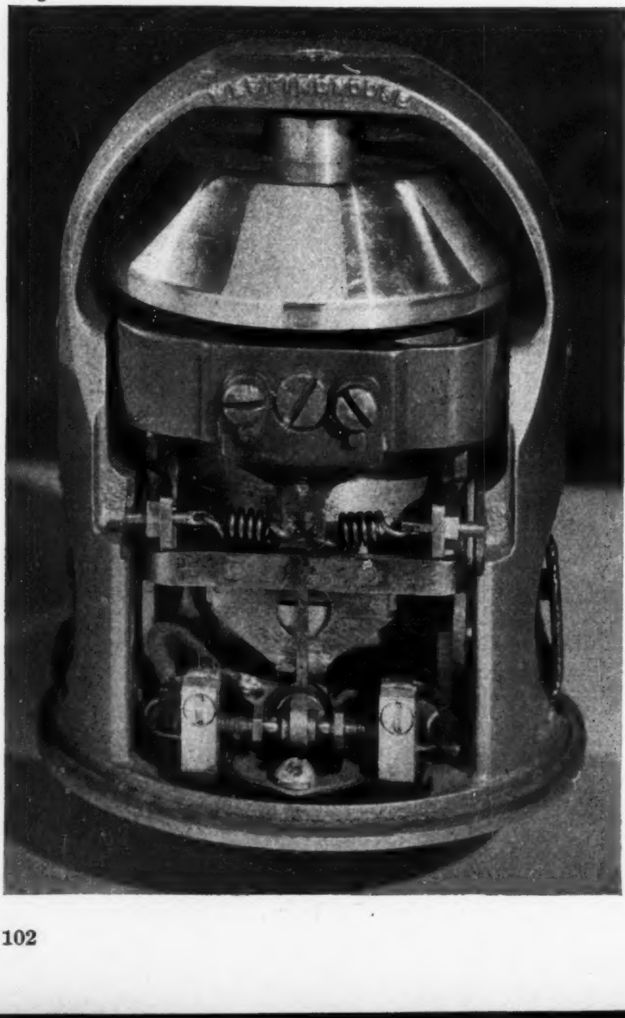
When the rotor of *Fig.* 1 is spinning about axis No.

1 with an angular velocity ω_1, a couple or torque applied to the gimbal supports about axis No. 2 to impart an angular velocity ω_2, causes the spin axis to rotate or precess about axis No. 3 with a velocity ω_3. This latter rotation about an axis at right angles to both the axis of spin and applied torque is gyroscopic precession. It stops when the spin axis, No. 1, moves 90 degrees and aligns itself with the axis No. 2 of the applied torque.

Direction of precession is fixed by the directions of spin and of the applied couple, and is such as to result in an increase in angular momentum about the axis of the applied couple. Therefore, precession is in the direction that places the vector of spin torque in the same direction as the vector of applied torque. The direction of a torque or angular-momentum vector is conventionally taken as the direction a right-hand thread moves if turned by the torque. In *Fig.* 1, then, with the gyroscope rotor turning counterclockwise to establish an angular momentum vector M pointing upwards, a clockwise couple represented by ω_2 and vector K causes a clockwise precession of the spin axis, ω_3.

Although gyroscopic effects are observed in practically all forms of rotating bodies, it is customary to think of a gyroscope as a ro-

Fig. 3—Below—This gyro-stabilized turret control for airplanes employs a rate gyro



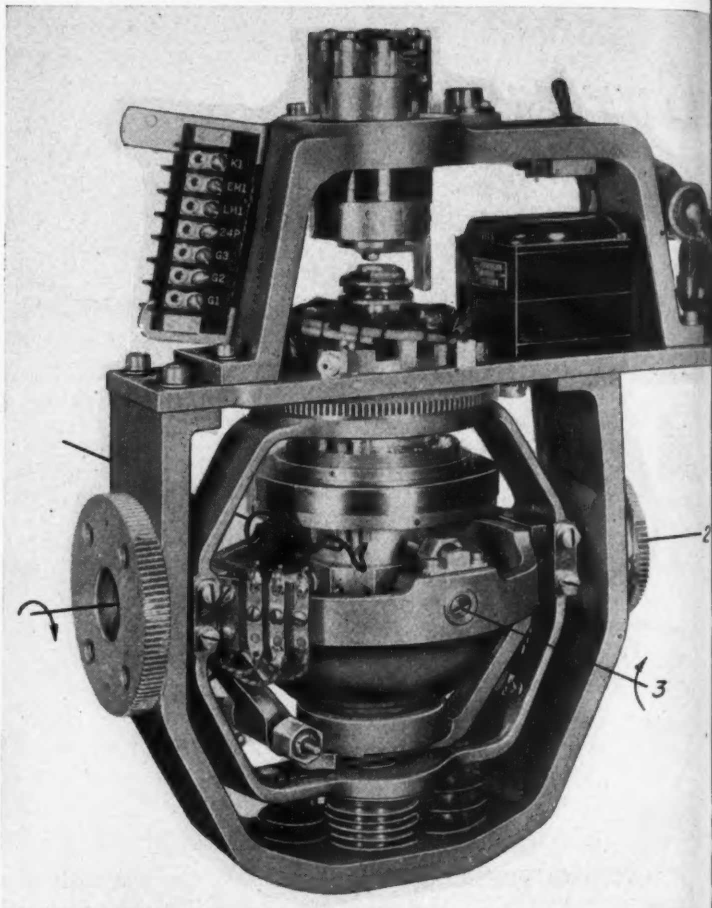


Fig. 4—Above—This position gyro is used to supply a true vertical reference in the presence of roll and pitch

tating mass having certain practical restrictions on its moment of inertia and motion. Six degrees of freedom are required to analyze mathematically a free mass moving in space, three for linear motion in three mutually perpendicular planes and three more for angular motion about three mutually perpendicular axes. But, if the center of gravity of the mass remains fixed, only angular motion can occur and hence only three degrees of freedom are required. A gyroscope having three degrees of angular freedom is called a free or neutral gyro.

To simplify the analysis, the gyroscope is made so that the spinning mass is the principal inertia and is statically and dynamically balanced about its axis. Also, all moments of inertia are equal about the axes perpendicular to the spin axis and passing through the centroid. Consequently, the free gyroscope, with one degree of freedom taken by the spinning mass, is relatively simple to analyze, since rotation is usually constant, and only two degrees of freedom remain to be considered.

Models and Effects: A toy gyroscope top demonstrates the precession and at the same time indicates the magnitude of precession torque. Although this top, *Fig.* 2, when rigidly supported has only one degree of freedom, that of the spinning mass, three degrees are obtained by supporting only one end. When one end of the spinning top is placed on a sup-

K. A. OPLINGER entered Westinghouse Research Laboratories in 1928. His first work there was on recorders for talking-picture equipment, and he helped develop a portable type for the fast-growing newsreel industry of those days. His next efforts were devoted to the regulator field and he was in on the early development of such notable devices as the Silverstat. During the war he helped produce the antenna positioner for the SCR-270 radar set of Pearl Harbor fame and assisted in development of the voltage regulator used by the Army as standard equipment in its bombers.

His pet project was probably the gun-turret stabilizer that Westinghouse designed for the Army's bombers. "There are no laboratory tests", he contends, "to compare with the experience of sitting in a B-25 bomber as it fires a 50-caliber barrage at targets towed by darting, twisting fighter planes". Recently he has had much to do with the research behind a new gyroscopic automatic pilot as well as the actual flight testing of early models.

A native of Taylorville, Illinois, Oplinger taught three years at Purdue before joining Westinghouse in the Transformer Division at Sharon in 1925. A graduate of Purdue University, he obtained his B.S. in electrical engineering in 1922.

port with the spin axis approximately horizontal, the axis dips slightly with several small oscillations and then precesses in a horizontal plane about a vertical axis. The weight of the gyroscope, acting about the point of support, applies a torque to the spin axis. The resulting precession is continuous since the applied torque rotates with the precession. Therefore, the spin vector, in trying to align itself, is continually moving toward the position occupied by the torque vector.

The ability of the gyroscope top to support itself in this maner by precessing can be explained by the simple relation $T = I\omega_s\ \omega_p$, where I is the moment of inertia with respect to mass of the spinning wheel about its axis, or mass times radius of gyration squared (pound-inch-seconds²), ω_s is the spin velocity, ω_p the precessional velocity (both in radians per second), and T the torque (pound-inches) acting about a horizontal axis perpendicular to both spin and precession axes. The units of torque in the weight or force system are pound-inches. For consistency, the units of moment of inertia necessarily must be in the same system. These are

$$I = \frac{W}{g} K^2 \text{ or } \frac{W}{LT^{-2}} L^2$$

Dimensions are cancelled to equal WLT^2 or pound-inch-seconds².

With constant spin velocity, the top would precess in a fixed plane at a constant rate were it not for the friction loss at the point of support. This loss is supplied by the potential energy of the top, which decreases slowly as its free end falls. Where the angular momentum of the top is decreased by friction at the spin bearings, the precession rate of the top must increase as the spin velocity ω_s decreases to maintain the balance between gyroscopic torque and torque produced by weight of the top. In many toy gyroscopes friction about the spin axis is so large that its angular momentum rapidly decreases, soon increasing precession rate to the point where the top falls off its support.

In determining the magnitude of forces obtainable from gyroscope rotors, reference to the simple top of *Fig.* 2 shows that it supplies a torque equal to the

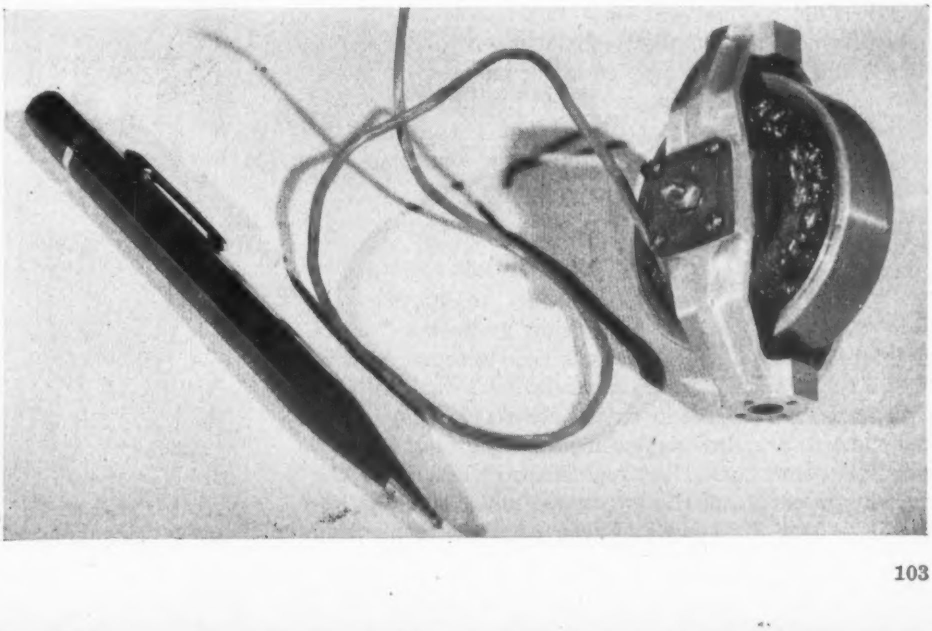


Fig. 5 — "Inside-out" gyroscope rotor which gives a high angular momentum per unit weight

moment of its weight about the point of support (approximately 0.5 pound-inches). The rotor has a moment of inertia of 0.00025 pound-inch-seconds^2 and can be given a spin velocity of approximately 300 radians per second by means of a string wound about the axle. Substituting these values in the torque equation, precession velocity is

$$\omega_p = \frac{T}{I\omega_s} = \frac{0.5}{0.00025 \times 300} = 6.67 \text{ radians per second}$$

If, then, the top is supported as shown in *Fig.* 2, precession velocity, ω_p, is 6.67 radians per second. Also, if the gyroscope is gimbal supported as in *Fig.* 1, and given a velocity of 6.67 radians per second about axis No. 2, a precession torque of 0.5 pound-inches appears about axis No. 3.

Angular momentum, or product of moment of inertia and spin velocity, is a convenient constant for evaluating effectiveness of a gyroscope. For example, the top of *Fig.* 2 has an angular momentum of 0.075 pound-inch-seconds and therefore develops a torque of 0.075 pound-inches if given a velocity of one radian per second about an axis at right angles to both the spin and torque axes.

Types of Gyroscopes: Practical applications of the gyroscope are divided into two general classifications of position or rate type depending upon the principal gyroscopic effect employed. The gyroscope is classified as a position type in applications where it supplies a position reference. Position gyros are freely gimbaled and make use of the "space rigidity" effect which tends to hold their spin axis fixed in space in the presence of angular disturbances. In applications where the primary function of the gyroscope is to sense angular velocity or rate the gyro is classified as a rate type.

Position Gyroscopes: A position gyroscope is freely gimbaled so that its spin axis can move in any angular direction. If the spin axis is placed at any angle, its rigidity tends to maintain it at that angle.

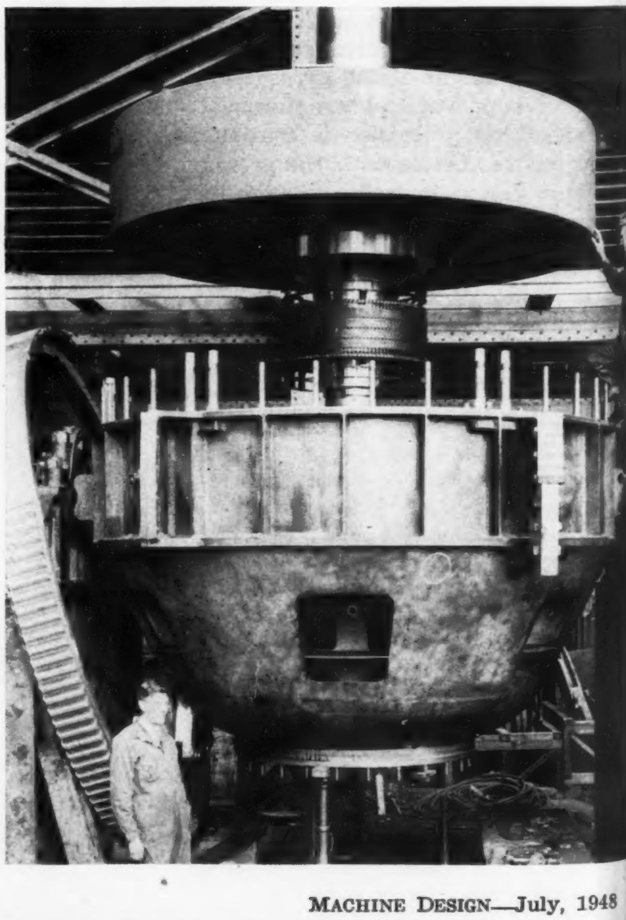
Spin axis No. 1 of the gyro in *Fig.* 1 can be used on a ship to supply a true vertical reference in the presence of roll and pitch. To make use of this reference it is necessary to provide a measure of the angular deviation between the gyroscope and the ship. One possible method is to use two magnetic pick-up coils to measure angular displacement about axes Nos. 2 and 3. The pick-up coils are mounted to move with the ship and their associated armatures are attached to the inner gimbal so that output signals are proportional to the roll and pitch angles of the ship.

Gyro Rigidity Not Absolute

In attempting to use a position gyroscope for an absolute position reference, it is soon discovered that "rigidity in space" is only a relative term. A free gyroscope can be made extremely rigid in space or resistant to angular displacements, by giving it large angular momentum. But regardless of how large the angular momentum, the gyroscope never remains absolutely fixed in space. Large angular momentum merely results in a slower precession or drift for a given applied couple. Small couples due to bearing friction or air resistance are always present and even the smallest will in time cause the gyroscope to change position. The rate of movement depends on the care taken in design and drift of the spin axis and varies from a few degrees per minute to a few per day. Consequently, the problems associated with the application of position gyroscopes are more numerous than those found in the application of rate gyros. It is necessary to keep all external torques on a position gyro extremely low since any torque results in precession and angular deviation of the position reference. This requires considerable care in the design and construction of the gimbal supports and in the servo-system used to measure the positional deviation of the source.

To prevent a continuous drift of the spin axis from the vertical due to external torques, a free-position gyroscope is usually loosely coupled to a pendulum. Such a gyroscope is shown in *Fig.* 3. The pendulum serves as a reference for true vertical and is coupled to the gyro by a small electromagnet that generates eddy currents in the rotor. When the gyroscope is vertical, electromagnetic forces acting on it are balanced; when not vertical, unbalanced forces produce a torque on the gyroscope causing it to precess to the vertical position. In this design, the gimbal assembly is slowly rotated to cancel the disturbing effects of unbalance and unequal bearing friction. This

Fig. 6—Below—This huge rate gyro stabilizes a 5000-ton yacht by limiting the roll due to impacts of waves



position gyroscope with its servo-system, can supply output signals representing true vertical in the presence of roll disturbances as great as plus or minus 30 degrees, with an accuracy of one-tenth of a degree.

The fact that a position gyroscope supplies the stimulus for a position-regulated system also increases problems of stabilization as compared with those experienced with a velocity-controlled system using a rate gyro.

Rate Gyroscopes: The rate gyroscope, *Fig.* 1, has only one effective degree of freedom since the outer gimbal is rigidly fixed to the system being controlled, which might be, for example, an airplane. If axis No. 2 is fixed parallel to the longitudinal axis of the aircraft, angular velocity in roll results in precession of the gyro rotor about axis No. 3. The direction and magnitude of the precession torque depend upon the direction and rate of roll of the airplane. Pick-off and amplifying elements responding to precession about axis No. 3 control the ailerons

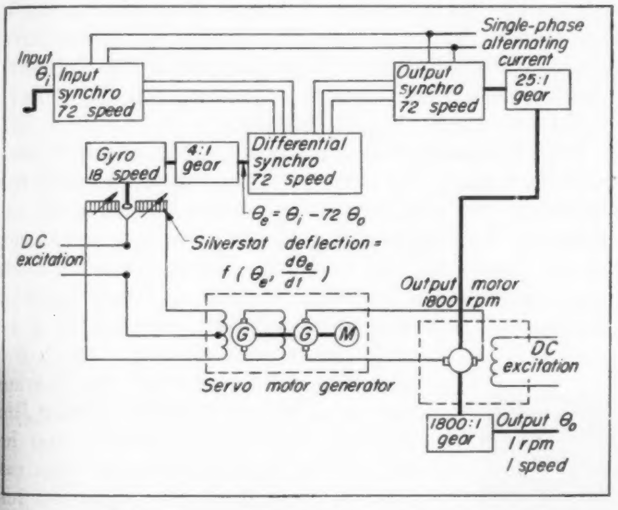


Fig. 7—Angular movements of the input and output synchros are compared by the differential synchro, whose output, Θ_e, is the difference or error between the two. This output angle is applied to the gyro, which deflects either Silverstat, depending on direction of error. Deflection is a function of not only error but also rate of change of error. The combination gives improved performance. Principal time delays are in motor and generator field and armature circuits

and therefore the roll velocity of the aircraft.

A simple rate gyro is shown in *Fig.* 4. Motion about axis No. 2, which is parallel to the plane of the paper produces a precession about axis No. 3 perpendicular to the paper. Motion about the precession axis is restrained to a very small angular deflection by two stationary contacts mounted on the assembly base. A common movable contact is fixed to the gyroscope. By placing a slight unbalance in the gyroscope wheel, the center contact is given a forced vibration so that one pair of contacts is continually made and broken. The frequency of contact equals the frequency of vibration but the contact duration is proportional to the precession torque.

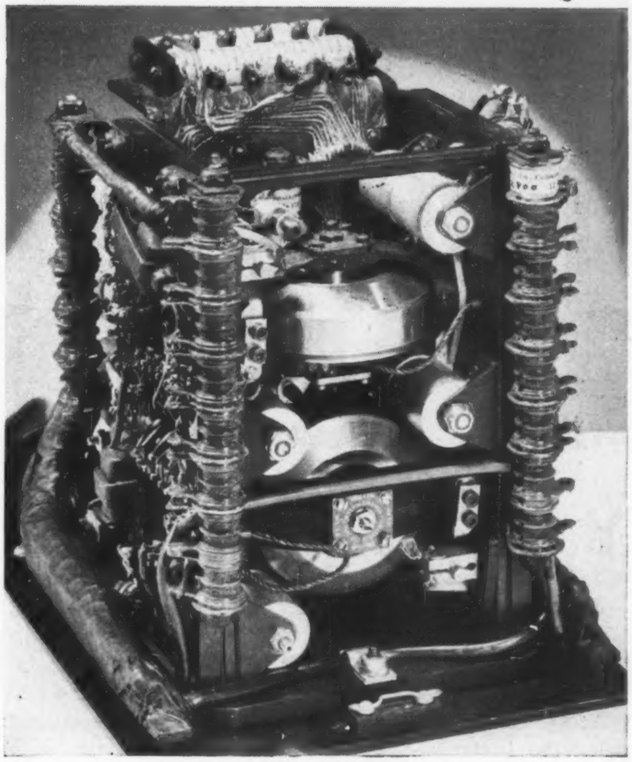


Fig. 8—Heart of the new automatic pilot are three rate gyroscopes whose rotors spin at 12,000 rpm

Thus effective current is proportional to torque about the precession axis.

This gyroscope is built to co-ordinate simple gyroscopic stabilization with an externally supplied signal. This is accomplished by placing two small electromagnets on the frame supporting the gimbal. The magnets are energized in proportion to the magnitude and direction of the signal and supply an equivalent torque about axis No. 3. A gyro-stabilized, velocity-controlled system consists of mounting this rate gyroscope on a rotating output member so that the gyro responds to the angular velocity of the system. The contacts control a hydraulic or electric servomechanism whose output velocity depends in both magnitude and direction on the resultant of the torques supplied to the gyro by both the electromagnets and the angular velocity of the system.

When torque from an external signal closes one pair of gyroscope contacts the entire system is rotated and the gyro develops an opposing precessional torque proportional to the system's angular velocity. When the two opposing torques are equal a hovering contact condition is obtained resulting in a stabilized velocity. Any deviation in velocity as might result from load variations or angular velocity in space gives a change in pressure at the hovering contacts and causes the servomechanism to supply additional output torque to resist the deviation. Velocities as low as thirty degrees per minute have been controlled and stabilized by this small rate gyroscope.

Gyroscopes in Action: In some cases, as in the gyro-stabilizer developed for tank guns, both posi-

(*Continued on Page* 186)

Kirby—The Man Behind Less Wo

By Richard K. Lotz
Associate Editor, Machine Design

"YOU can't develop new machines with manpower. It takes ingenuity."

Such is the unequivocal answer of James B. Kirby to those who insist that new inventions can come only from highly-staffed laboratories. And Jim Kirby ought to know. His two hundred some-odd patents have all been developed without benefit of scientific instrumentation. They range all the way from electric window washers to variable-speed fluid drives, and include such devices as hydraulically controlled home ironers, automatic home dish washers, fluid delay clutches, and home cooling units operated by evaporation from circulated outside air.

Chances are the vacuum cleaner and automatic washer in your home are based on Kirby inventions. In fact no less than eight of today's automatic washers are based on and licensed under Kirby patent No. 1,969,176. Issued in 1934, it contains one-hundred and six claims!

The story of James B. Kirby comes close to being a saga of rags to riches. In place of a silver spoon in his mouth, Jim came into the world some sixty-three years ago with a gift. That gift was a talent for invention combined with a relentless tenacity inherited from sturdy Scots forebears.

Like Thomas Edison, he was considered a dull student in school. He simply did not have the time for studying dry academic assignments. Much more interesting was delving into the innards of a telephone, or the family talking machine. At one time his class was studying the grinding of wheat. Jim's teacher, knowing of his flair for gadgetry, asked him if he could make a flour mill. With the boundless self-confidence so characteristic of him to this day, young Jim assured her that he could. And he did. Using bits and scraps from his father's workshop, he patterned his model after the big wheels he had seen at the commercial mills, and even incorporated provision for screening.

Recalling that episode recently, Jim chuckled nostalgically and observed, "It really wasn't much of a flour mill. But it worked."

It was while still in his early teens that Jim Kirby decided he would not spend his life as a salaried worker for anyone. Kirby senior had at first been a marine engineer on the Great Lakes, and later worked at building engines for large freighters. His modest salary seemed to young Jim small recompense for so many hours of work.

Even the crudest kind of experimentation requires tools and materials and both of these items cost money. And so Jim Kirby made up for the lack of family funds by working during his spare time.

Kirby's drafting board is situated in one of the many bright, cheery rooms of his Ohio home. "Had it not been for the incentive and protection afforded me by the United States Patent Office," says he, "I never could have helped to start new businesses with my inventions." Here he explains the mysteries of a patented ball type balancing mechanism

the Home

In those days the streets of Cleveland were illuminated by gas. It was Jim's job to light the lamps in his neighborhood each evening and turn them out again each dawn. His route was four and one-half miles long and for this work he received the princely stipend of $16.50 per month. In addition, weekends saw Jim in the press room of the old Cleveland *Leader*, assembling the Sunday sections of the newspaper into single units. Pay—one dollar for four and one-half hours of work.

Ingenuity Points the Way

Each evening on his tour of the gas lamps Jim passed the gaily lighted windows of a toy shop, the feature display of which was an electric train. He wanted that train, and as he walked his route, he wracked his brains to figure some way by which this treasure might be bought. But even with his extra earnings, there simply wasn't enough money. And then the solution came to him. He would make the electric train himself! Once again with odds and ends, screws purchased here and wire salvaged there, he contrived his train, complete with home-made electric motor. The tracks he pressed from strips of tin in a form mounted on the cross carriage of a lathe. This resourcefulness has stood Jim Kirby in good stead throughout the years. Just recently, with carpenters virtually unobtainable, he and two farm hands erected a 38 by 40-foot workshop on his 200-acre Ohio farm. Not only is it sturdily constructed, but in the process, Jim hit upon a new concept in foundation design—but that's another story.

Perhaps the most daring adventure of Kirby's boyhood concerns the private telephone exchange he designed and built when he was seventeen. This time he used parts which had been scrapped or rejected by the telephone company. His system operated over unused lines among the myriad wires strung up by the company. For three years, unsuspected by the telephone company, Jim and fifteen of his young friends operated their ultra-exclusive communications system, and never bothered "Central" once.

While Jim Kirby's outstanding success can be attributed to many qualities, at its root, like an impregnable bulwark, is a confidence in self which is virtually absolute. His unswerving dictum is "Nobody can beat me!" In cold print that reads like rampant egotism, but for Jim Kirby it has paid off—and you can't argue with his kind of success.

Asked what his advice to young men eager to follow in his steps might be, he quickly responds: "First, a young fellow should know what he wants to do with his life." Not an idle preachment this, for its reflects a decision he himself made when entering the third grade of high school. His heart was set on becoming a chemist; yet the school authorities insisted he study languages instead of chemistry. This made no sense to Jim and so he quit school at the end of his third year and went to work in a small experimental machine shop.

Kirby is certain that not everyone can become a

WIZARD.

West-Side Has a Young and Tender Edison.

Cleveland has a 13-year-old boy who bids fair to astonish the world as an inventor and electrician.

This singularly gifted boy's name is Jas. B. Kirby. He is a son of Jas. D. Kirby, of 54 Marvin-av.

JAS. B. KIRBY.

Master Kirby is a born electrician. He presents the only known instance of a child born with a knowledge of electricity. But a little over a year ago, when the first principles were explained to him, the boy seemed to understand them intuitively.

Among the long list of inventions for which Master Kirby is responsible is a telegraph instrument, galvanometer, magnets, induction coil, double carbon electric light and a microphone. It is claimed that the last named instrument will carry the voice 2000 miles. Young Kirby has just completed a motor, which is a complete success, and he is at present engaged upon a 16-cell battery. Young Kirby is known among his friends and associates as the wizard of the West Side.

Early evidence of Kirby's "flair for gadgetry" is this clipping from an old Cleveland newspaper

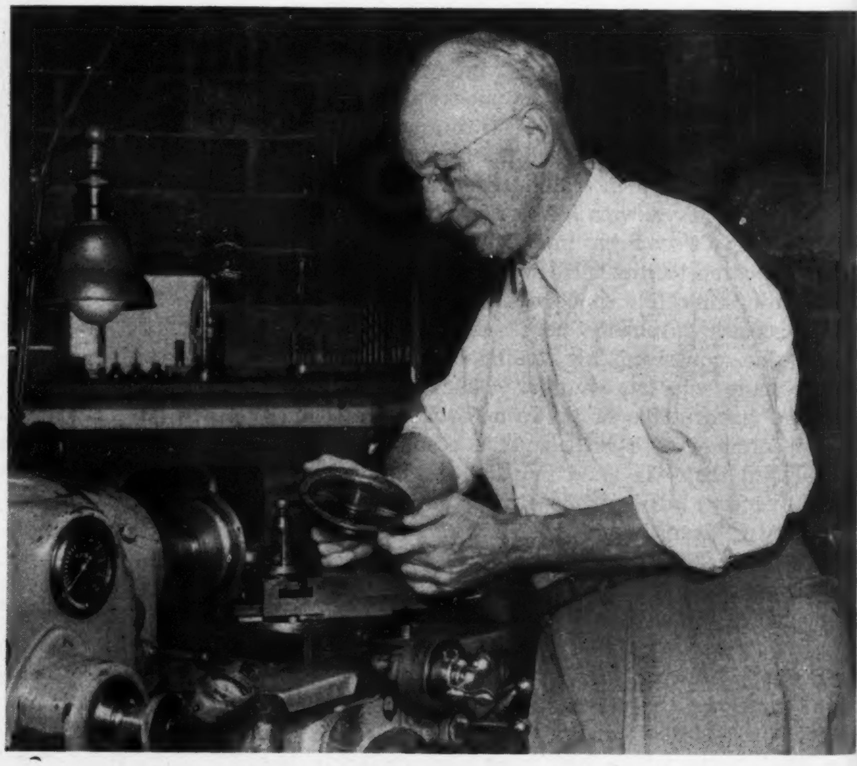
successful inventor. Says he: "If a young man has no strong inclination for mechanics, he had better train for something else. It may be that potential ability in any field is inherited. If it's there, training can bring it out. If it's not, it can't be brought out."

The Kirby system for inventing draws heavily upon imagination, inspiration, the subconscious, and a sense of realistic practicality. That last mentioned characteristic is evidenced in Kirby's admonishment, "Make sure that the thing you are going to invent is greatly needed and will have a mass market. In this way you will insure rendering the greatest service as well as a substantial return on your investment of time, talents and energy."

Jim Kirby has invented more practical devices during the last three years than at any other comparable period in his life. He ascribes this to the fact that he has learned what to think and what not to think as he invents. "During my early years", says he, "I wasted a lot of valuable time barking up wrong trees. A fellow has to learn which of the ideas his imagination feeds to him should be followed or rejected."

When Jim Kirby sits down at his drafting board, it is to put on paper the outlines of a machine or mechanism which has already been fully developed in his mind. His method is first to conceive a reasonable scheme by which the result desired might be achieved. Then follows a period of watching the mechanism operate in his mind's eye. Driving home from town, while shaving, while eating, while dressing—at any and all times he watches and studies the mechanism as it works in his mind's eye. Soon he perceives a flaw, or something that might be done in a more direct, simpler manner. The mental image is redesigned, and the process of watching and studying continues. This procedure is repeated over and over many times before he is satisfied that the new invention will do what he wants it to in the manner he wants it done. Often, after concentrating on a problem for many days he will waken at an early morning hour with the complete solution before him. Then and only then does he put it on paper. There is no question in his mind but that his best work is done between the hours of 3 and 4 a.m., when his mind is fresh and rested.

The idea from which has sprung the modern, clean-lined Kirby vacuum cleaner of today saw its inception on a hot summer day over forty years ago. Young Jim was returning home and noticed a wagon



Kirby often makes the pilot models of his inventions in his modern basement workshop. A firm believer in learning by doing, he advises young men: "Get into a small company which makes machines. Work with your hands. Learn to make machine parts on the various machine tools. Get the feel of materials. Observe how all kinds of machines work. Store this information away in the back of your head. You can call on it later and combine it with ideas to create new machines." He adds emphatically, "And get started on your own as soon as possible"

parked in front of a neighbor's house. A chugging engine on the wagon drove a suction pump to which was attached a long flexible tube which extended up the walk and into the house. Upon inquiry, Jim found that the neighbor's rugs and carpets were being cleaned by a new "vacuum" process imported from England.

Opportunity Beckons

It was apparent to young Kirby that while this new service was a vast improvement over laboriously beating rugs by hand, still better would be a portable cleaner owned and operated by the housewife herself. He went to work trying one scheme after another, each failure giving birth to new hope for success, until finally, in 1906 he developed a unit which he believed would do the job.

That first model was assuredly a far cry from the Kirby cleaner of today. It comprised an upright drum at the bottom of which were two pails of water and on top of which was mounted a hand-powered pump. A flexible hose connected the cleaning nozzle to the water tank in which the dust-laden air was drawn up in bubbles and filtered before reaching the suction chamber and pump. An obvious drawback lay in the need for two operators. Further, the water in the pails soon became overloaded with dirt and the pails were messy and rather difficult to clean. Kirby quickly decided that water was not the best filter medium and developed a dry method to replace it.

His next model was considerably more practical and successful. Somewhat smaller but of the same general shape as its predecessor, its pump was driven by an electric motor and the dust-laden air was filtered by centrifugal action and a fabric separator. This action was achieved by shooting the dust-laden air into the lower portion of the drum through a tube fastened to the drum tangential to its periphery. The swirling action thus engendered threw the dust and dirt to the drum wall, while minute particles were caught by a cloth bag filter which surrounded the pump and motor. This 1907 Kirby cleaner was not, however, as convenient nor as portable as its inventor desired.

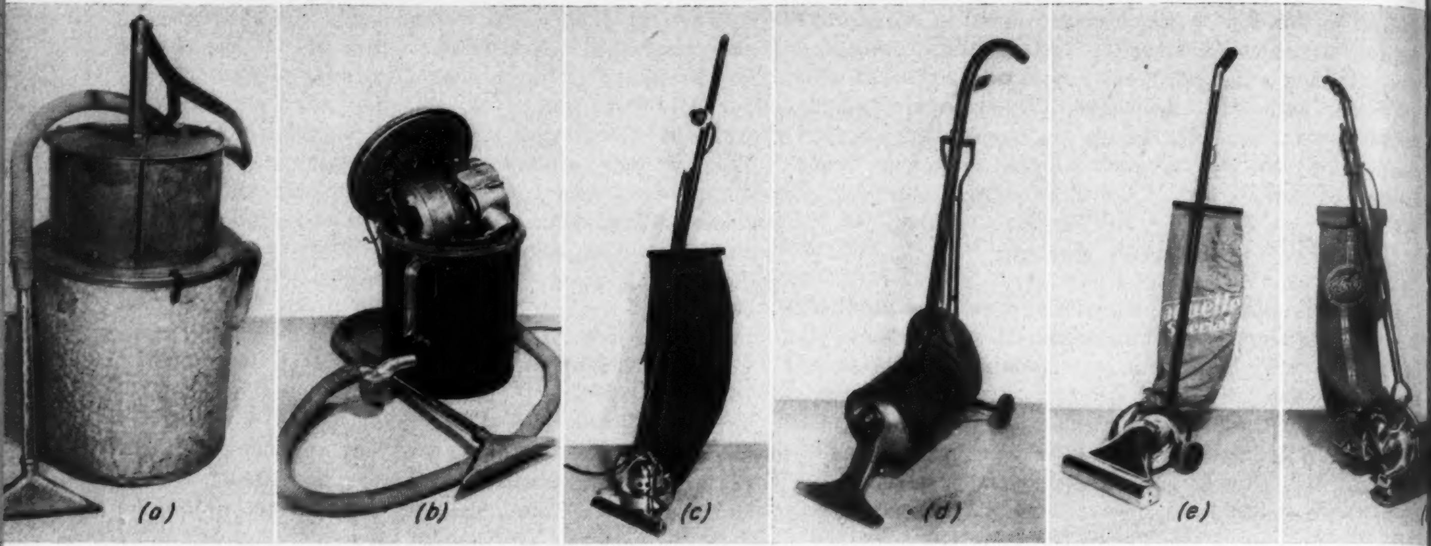
By this time it had become clear to Kirby that cleaning by suction alone was not completely satisfactory. Some means of agitating the pile of a rug was required. Thus, his next model incorporated a rotating beater. This model looked very much like a miniature of today's floor model, complete with filter bag suspended from its handle. It consisted, as Kirby puts it, of a "broomstick with a gadget at the end". The gadget at the end was an electric motor and fan built into an aluminum housing. The rotating beater was air driven by the developed suction. Another feature of this model was a glass-bowl "dust exhibitor". Fastened to the housing, it gave the operator continuous visible indication of the cleaning action.

This cleaner was destined to be manufactured by the Frantz Premier Co. of Cleveland. E. L. Frantz, a real estate man, sold Kirby an apartment house. During the negotiations Kirby interested Frantz in his new cleaner and Frantz decided to manufacture it. Operations got under way in 1910 and the cleaner met with gratifying success.

In February 1940, at a banquet sponsored by the National Association of Manufacturers, Jim Kirby received the association's Modern Pioneer Scroll of Achievement from W. T. Holliday. Reserved to honor men who have helped to pioneer new industries, the scroll reads: "Awarded to James B. Kirby—A Modern Pioneer on the Frontier of American Industry, in recognition of distinguished achievement in the field of science and invention which has advanced the American standard of living"

Kirby now began work on a cleaner to serve housewives in rural communities not having access to electric power. His first effort, marketed in 1912, was dubbed the "grasshopper", which indeed it resembled quite strongly. It comprised a cast nozzle fastened at the front end of a short cylinder in which was a cloth bag filter. At the rear end of the cylinder was a bellows, the back end of which was mounted on two wheels. When the handle fastened to the top of the cylinder was pushed forward and downward, the nozzle slid forward across the rug, while the wheel-mounted rear end of the bellows remained stationary. Thus, the bellows expanded, sucking in air and dirt from the rug. At the end of the forward stroke, the handle was lifted, permitting the bellows to contract, the rear end moving forward on its wheels. Like its immediate predecessor, this model was equipped with a dust exhibitor.

While the "grasshopper" did a fair



EVOLUTION OF A VACUUM CLEANER. (a) Hand-pumped model used water as filter medium, required two operators; (b) First electric model filtered by centrifugal action and fabric separator; (c) First floor-type model used motor-driven fan and air-driven brush; (d) The "grasshopper" was nonelectric—sucked up dirt by action of bellows; (e) The "Vacuette", also nonelectric, had fan driven from wheels through gearing and overrunning clutch; and (f) "The Kirby", a modern floor-type cleaner, has clean lines, incorporates a clean-out tray and convenient foot-regulated nozzle-height adjustment

job of cleaning, Kirby recognized that the pushing and lifting required of the operator should, if possible, be modified. And so his next model, almost identical in appearance to modern floor type cleaners, necessitated only that the operator push it across the rug. Nonelectric, its fan was powered from the wheels through a roller-type overrunning clutch driving a wheel and worm. Interposed between the clutch and worm wheel was a coil torsion spring. Each time the machine was pushed forward the clutch wound up the spring for about a revolution, the spring then drove the worm wheel which in turn drove the worm on the fan shaft. When the machine was pulled back, the clutch released, permitting the fan to continue spinning under its own momentum. The purpose of the torsion spring was, of course, to give the fan an extra push each time the machine was pulled backward.

A New Business Is Born

At this juncture World War I came along and Jim Kirby, considered too old to carry a gun, became a dollar-a-year man. As such he was assigned to the Cleveland area and served as expediter with the Scott and Fetzer Company. This company, which before the war had manufactured automobile parts such as cam rolls, valves, pump shafts, and the like, was engaged in the production of Very signal pistols. At the conclusion of hostilities, Kirby informed Messrs. Scott and Fetzer that he had developed a household appliance in which they might be interested. Upon demonstration of his new nonelectric cleaner, a royalty agreement was drawn up and in 1919 the "Vacuette" was placed on the market. Over 1,500,000 were sold all over the world.

By the time the early 1920's rolled around, it became clear that the real mass market for home appliances of the future would be in electrically powered units. In recognition of this trend, Kirby developed and Scott & Fetzer produced the Vacuette Electric. The principle upon which that 1925 model was built persists in "The Kirby" cleaner of today.

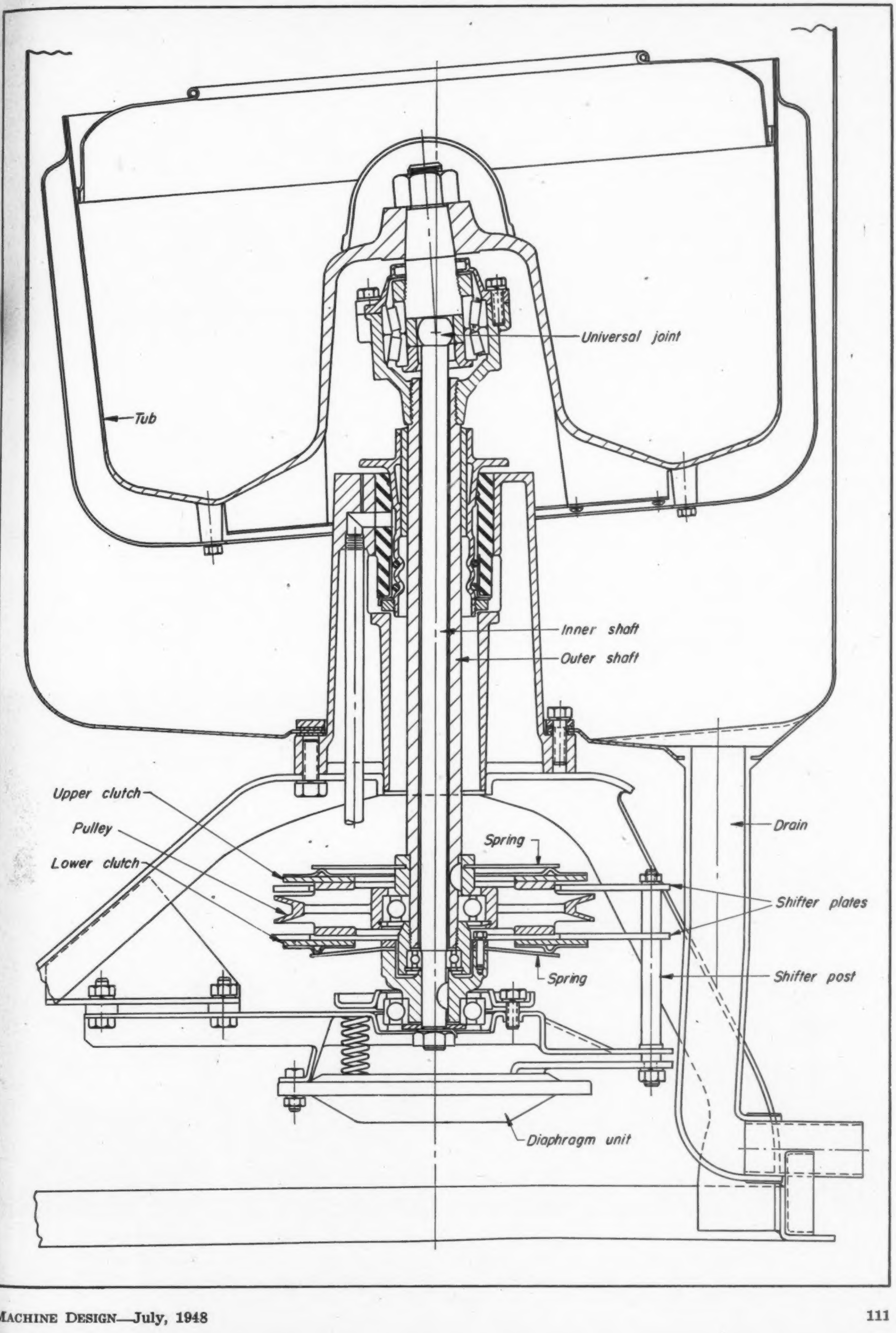
"BOUNCING BASKET" WASHER →

Section through new Apex automatic washer shows how Kirby's "bouncing basket" washing principle is achieved. When water is automatically drained from the diaphragm unit at the machine base, the coil springs press the top surface of the diaphragm downward, lowering the shifter posts and plates. This action disengages the lower clutch face from the bottom friction surface of the pulley and permits the upper clutch spring to press the upper clutch face firmly against the top friction surface of the pulley (pulley is driven by V-belt direct from constant-speed motor). At this juncture the inner shaft is held stationary and the outer shaft is spun. Since the tub shaft is mounted in bearings set at a tilt, as the outer shaft spins the tub describes what might be termed a swiveling rocking motion, which bounces the clothes up and down in the soapy water.

Next, water is automatically valved—at line pressure—into the diaphragm unit and the three shifter posts raise the shifter plates. This action lifts the upper clutch face off the top friction surface of the pulley and at the same time permits the spring of the lower clutch to press the lower clutch face firmly against the bottom friction surface of the pulley. Thus the outer shaft is held stationary while the inner shaft is spun. As it spins it drives the tub by means of the universal joint. This is the extracting cycle during which water is flung from the clothes by centrifugal action. Bouncing and extracting occur, of course, at the same speed

Essentially, it consisted of a power-and-fan unit on wheels, to which various auxiliary units could readily be attached.

Since 1925, succeeding models of "The Kirby" have introduced new design features, each of which has


Universal joint
Tub
Inner shaft
Outer shaft
Upper clutch
Pulley
Lower clutch
Spring
Drain
Shifter plates
Spring
Shifter post
Diaphragm unit

made the machine a more convenient and increasingly effective cleaner. These have included addition of a built-in light at the top of the machine, a clean-out tray which makes removal of the bag unnecessary, an improved nozzle-height adjustment mechanism, a more efficient fan, and numerous other innovations.

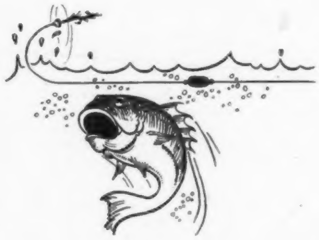
Just as Jim Kirby's nonelectric vacuum cleaner started Scott & Fetzer in a new business in 1919, his original spinner type clothes washer started another Cleveland business in 1916. This was the Laun-dry-ette Mfg. Co. In its heyday, with the late Arthur Betz at its helm, the company paid 100% cash dividends on its stocks each year. Kirby's washer, the grand daddy of today's spinner-agitator automatics, was dubbed the "Laun-dry-ette". It combined for the first time washing and extracting in a single tub, making it unnecessary for the housewife to touch the clothes until after they had been damp dried.

Obsolescence Exacts Its Toll

For ten years Laun-dry-ette Mfg. Co. enjoyed uncommonly lush prosperity and for ten years Jim Kirby importuned its top management to improve the washer from year to year. His urgings were to no avail and in 1926 the company went bankrupt. This experience made a lasting impression on Kirby. Today he insists on maintaining his designs three years ahead of models in current production.

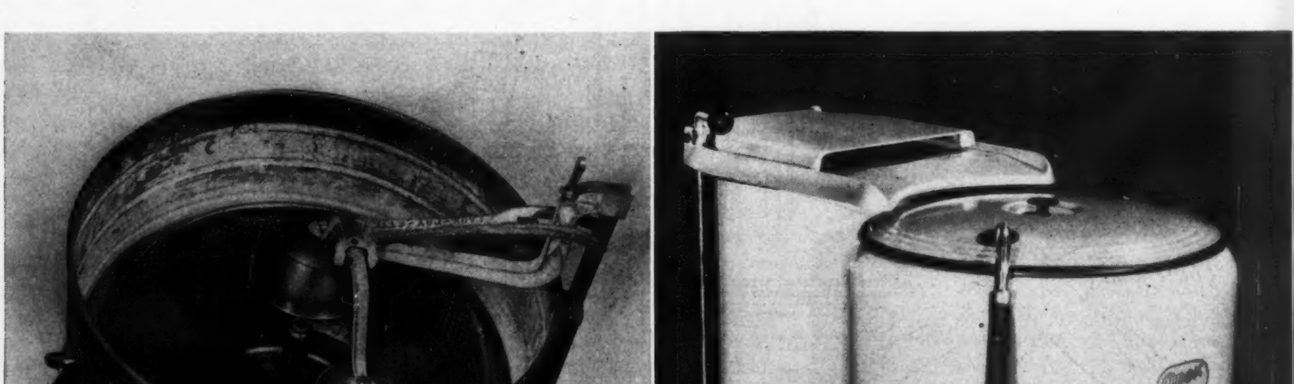
Although the Laun-dry-ette did a thoroughly satisfactory job of washing and damp drying, it had one drawback which its inventor was determined to overcome. Its tub was rather large in diameter and, since it was not balanced, caused the machine to shake during the extracting spin. Kirby's next machine contained two tubs—one for washing by agitation, the other for spin drying. To hold off-balance of the spinner at a minimum, it was made small in diameter and comparatively high.

Can You Invent it?



Here's a tip from James B. Kirby:

There is a need in the sporting goods field for a device which, clamped onto a fishing line several feet ahead of the bait during trolling, will cause the bait to dart and jump at frequent intervals. Mr. Kirby has no patents on such a device and offers this tip as an opportunity for young designers. Who knows, perhaps you can invent it and sell it to a sporting goods manufacturer!



Grand daddy of today's spinner-agitator automatic washers was the "Laun-dry-ette", left, the first to combine washing and extracting in one tub. At right is two-tub washer in which extracting tub was made high and small in diameter to minimize off-balance

This two-tub job was first placed on the market in 1927 by Apex Electrical Mfg. Co. of Cleveland. During the ensuing years it has seen many improvements and today the company is in pilot-plant production of a new fully automatic washer based on a recent Kirby invention. The washing principle employed in this Apex automatic is brand new. Under the control of automatic cycling, the clothes are "bounced" in a rotary tub of soapy water 550 times per minute, rinsed and spun damp dry.

In discussing the new "bouncing basket" principle of the new washer, Clarence Frantz, president of Apex, pointed to another unique Kirby trait. Said he: "Jim Kirby has a penchant for seeking uncharted courses—a flair for the unorthodox." One could almost say that Kirby's business methods are unorthodox too. In drawing up royalty agreements with manufacturers, he is more concerned about insuring a fair profit for the company than he is about getting all he can for himself. He believes that friendly relationships with his business associates are more important than immediate profits. This policy has paid off, for those with whom he conducts business feel constrained to deal with him in utter fairness.

Like most outstandingly successful men, Jim Kirby is an individualist and has strong convictions. In speaking of modern education, he remarks with some feeling, "I think college education today is slanted in the wrong direction. It fits people primarily for the social life; it doesn't fit them for work. If I were running this country, I'd see to it that everyone was trained to take care of himself."

And so Jim Kirby at 63, restless and energetic, continues to explore his uncharted courses into the future. At the laboratory on his farm he probes into dozens of problems, seemingly all at once. A new method for varying the power of a hydraulic drive, a brush-cutting machine for clearing wooded land, a new deep-sea fishing reel and, of course, improved vacuum cleaners and automatic washers to lighten still further the labors of housewives everywhere.

New Hydraulic Fluids Won't Burn

UTILIZING the common knowledge that water will not burn, scientists at the Naval Research Laboratory, Washington, D. C., have developed the first successful noninflammable hydraulic fluids. These "hydrolube" fluids, so named because of their water base, eliminate the fire hazard resulting from use of petroleum-base fluids in hydraulic systems, particularly in aircraft.

Use of the water-base fluids in the landing gear, brake and flap-control hydraulic systems of military planes will increase their combat efficiency by preventing fires caused by bullets or shrapnel ripping open the high pressure hydraulic lines. In addition, their use will give added safety to both military and civilian aircraft by eliminating a major fire hazard created by rupture of hydraulic lines in emergency landings.

The hydrolube fluids have stood up under two years of severe tests in Navy planes and are currently being tested by the Civil Aeronautics Administration for commercial airline use. Other tests designed to further improve their performance are continuing in an aircraft mock-up at the Naval Research Laboratory. The Navy Bureau of Aeronautics, which has sponsored the hydrolube development project along with the Office of Naval Research, has approved the water-base fluids for use in the hydraulic systems of most types of Naval aircraft in the future.

The first hydrolube fluid developed after four years of research possessed the following characteristics: It would not burn; its freezing point was 82 degrees below the freezing point of water; it was much less corrosive than water; it provided much greater freedom from packing deterioration and leakage than present hydraulic fluids; its lubricating properties were satisfactory; and all ingredients were made of chemicals of native American origin.

At the outset, researchers realized that use of water as a base for a noninflammable hydraulic fluid would be contingent upon the location or development of an antifreeze component, a thickener, corrosion inhibitors, a wear preventive, and an organic chemical to make soluble all the ingredients. They first turned to basic research and delved into such fundamental problems as why some fluids burn and others do not. Along the road of discovering the "why" of basic phenomena, chemists developed new methods of appraising the fire hazard of fluids and new methods of improving the lubricating properties of water.

Although the hydrolube fluids have been tested in Navy planes for over two years without failures, the scientists are still seeking to improve them. In the aircraft mock-up, three different types of aircraft piston pumps are in constant operation night and day, pumping the hydrolube fluids through the systems to test their performance. The mock-up simulates the conditions of a hydraulic system on an airplane. It is run for about 1000 hours and then all parts are inspected for such performance indices as wear, corrosion and packing attack.

Researcher uses goniometer to determine the contact angle of drops of "hydrolube" with a steel surface

Trapped Stresses

. . . how they can be created to improve the performance of machine parts

By Henry O. Fuchs
Asst. Chief Engineer
Preco Inc.
Los Angeles, Calif.

MOST designers and all good shop men are aware of quench cracks and of the distortions which accompany welds. As is well known, such cracks and distortions are caused by stresses set up within a piece when one part cools more rapidly than another. As a result of this knowledge, stress-relief annealing is often specified for complicated weldments and castings, and special high-temperature quenching is used in heat treatment.

Only in the last few years has the knowledge of this type of stress, which may best be called "trapped stress" but is also known as residual stress, been applied consciously to serve a useful purpose. Trapped stresses, deliberately produced by heat treatment, shotpeening, overstressing (*Fig.* 1) or other methods, help to carry loads and to increase the strength of parts against static and, especially, fatigue failure.

Stress analysis as taught in most schools and practiced in many engineering offices considers only the stresses produced by external loads. Yet a part will fail at a certain stress, no matter whether this stress is produced by external loads or trapped in it by some production process. Failure to give due consideration to trapped stresses is one reason why the stress analyst is viewed with some suspicion by the practical shop man who knows that a spring may operate very well at a calculated load stress above the fatigue limit or even above the yield strength, or that a bracket bent cold can be opened up quite easily although it is hard to close it. Observations such as these check well with the theory of stresses if due al-

Photo, courtesy Eaton Mfg. Co.

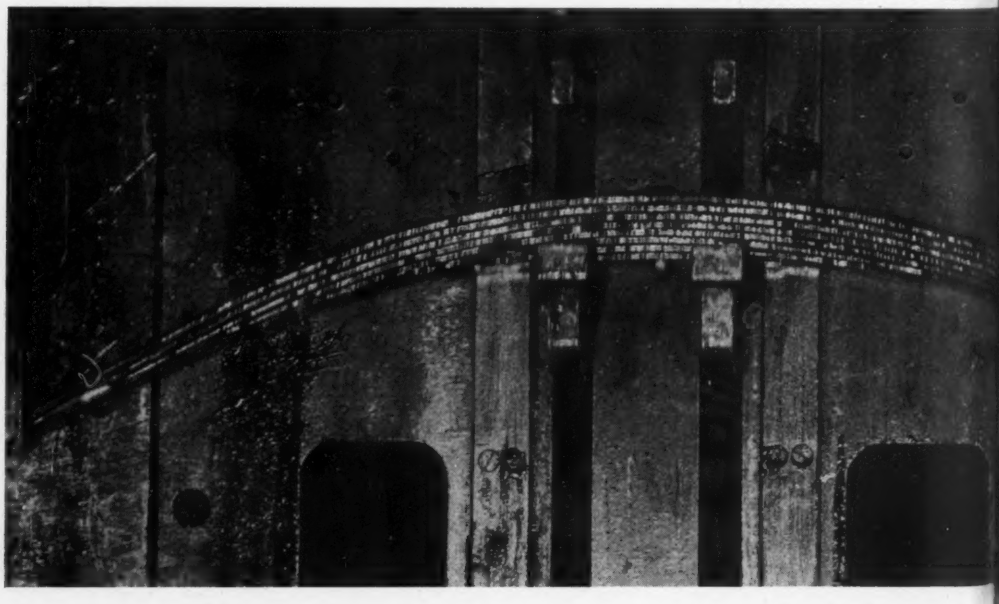


Fig. 1—Automotive leaf spring undergoing treatment in a prestressing machine for the purpose of inducing trapped stresses

lowance is made for the favorable or unfavorable effect of trapped stresses.

GUNS: A fairly old example of the deliberate use of trapped stresses is found in the manufacture of guns. Gun barrels are essentially thick-walled tubes. Ability to carry high internal pressures is highly desirable because it enables the gun to shoot farther and more accurately than the enemy's. However, the internal pressures which can be used are limited by the stresses which the gun barrel steel will withstand. These stresses cannot be decreased effectively by using barrels with thicker walls, the distribution of stresses in thick-walled tubes being such that the outer layers carry only a small part of the load and are relatively inefficient, *Fig. 2b*. The highest stress is at the bore which, in addition, is subjected to the intense heat of the firing.

Improving Conditions at Bore

The destructive stress in the gun barrel is tensile. Thus the gun can withstand higher pressures if compressive stress is trapped near the bore, where the load stress is high and temperature conditions severe. Since equilibrium conditions must be satisfied (you can't get something for nothing) this will result in a tensile trapped stress at some other region of the barrel—the outside. But the load stress is low near the outside and the temperature conditions are more

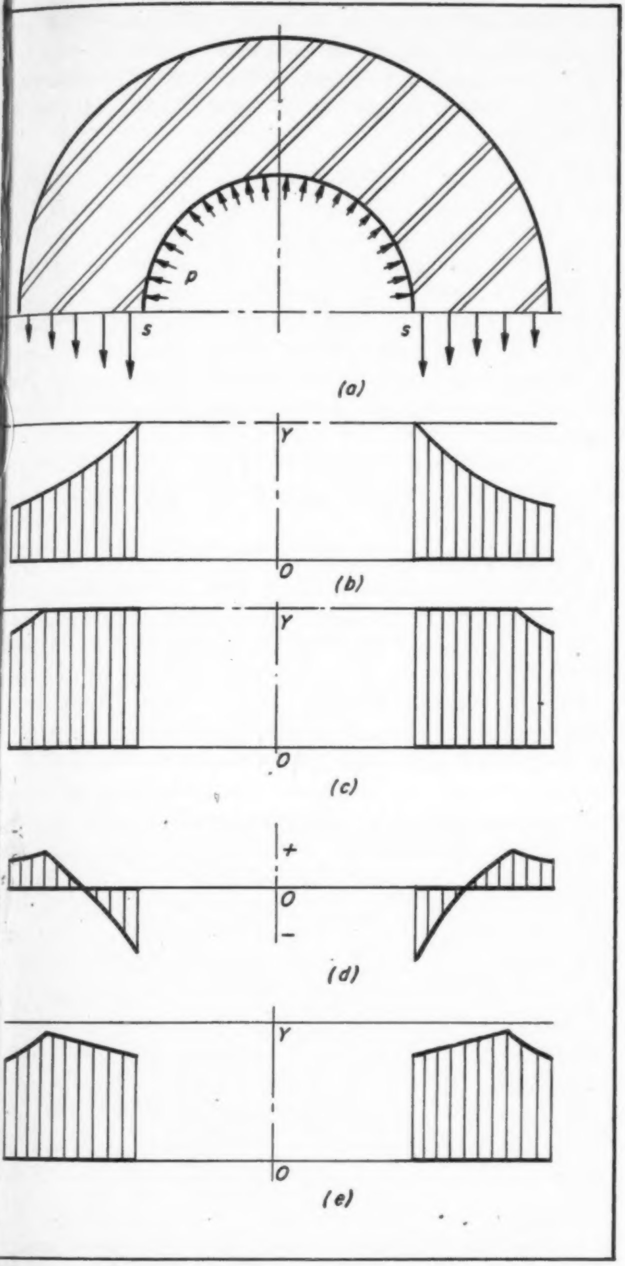
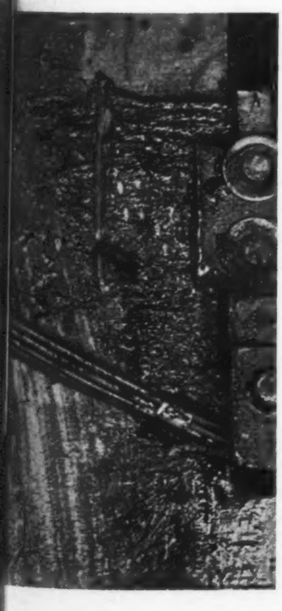


Fig. 2—Above—Distribution of stresses in a gun barrel (a) due to low internal pressure (b); during overstressing or autofrettage (c); after autofrettage, showing trapped stresses (d); and during firing after autofrettage (e)



Photo, courtesy Ford Motor Co.

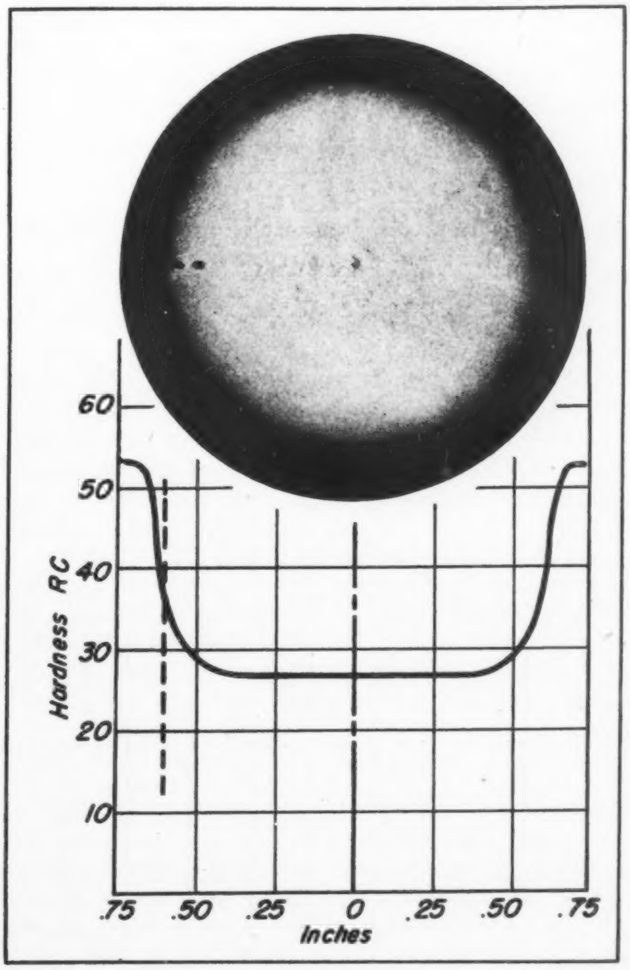


Fig. 3 — Right — Cross section through shallow-hardened truck axle showing 0.18-inch deep hard zone. Diagram shows hardness variation across section

favorable so that this added tensile stress is not harmful. The net effect of the trapped stress—compressive near the bore, tensile near the outside—is to combine with the unequally distributed load stress to give a more uniform total stress, *Fig. 2e.*

How Stresses Are Trapped

Various methods have been used to achieve the foregoing result. Winding wire under tension around the inner barrel is one (obsolete) method. Shrinking a hoop around the inner barrel is another. The most modern and most interesting method is called autofrettage. In this process the gun barrel is closed off at the ends, filled with liquid, and subjected to internal pressure until it expands so much that a permanent set remains. In this operation the bore of the barrel first reaches the yield strength of the steel and then progressively larger zones yield until finally the entire material of the barrel has reached the plastic stage, *Fig. 2c.* In this stage, the stresses all across the gun are fairly uniform. When the pressure is released the stresses decrease much more near the bore than near the outside. The bore reaches the zero stress when the outside is still highly stressed, but the stresses must decrease still more to reach a condition of equilibrium. Near the bore they decrease into the negative range and in this way a negative or compressive stress is trapped near the bore, *Fig. 2d.*

The logic of prestressing a gun barrel is very simple. Tensile service stresses are offset in part by compressive trapped stresses. The trapped compressive stress in one section is held in equilibrium by a trapped tensile stress in another region of the part, where the service stress is low. This simple line of reasoning has been known for quite some time. It explains, among other things, the modulus of rupture, which is usually much higher than the ultimate tensile strength.

AXLE SHAFTS: Newer and more interesting applications of trapped stresses are based on the knowledge that compressive stresses can be used to increase resistance against fully reversed service stresses, such as occur in the flexing of members or in the rotating beam test, and against torsional stresses such as those in coil springs. They can also be used to prevent brittleness by permitting local areas of incipient failure to yield and to adjust themselves without cracking.

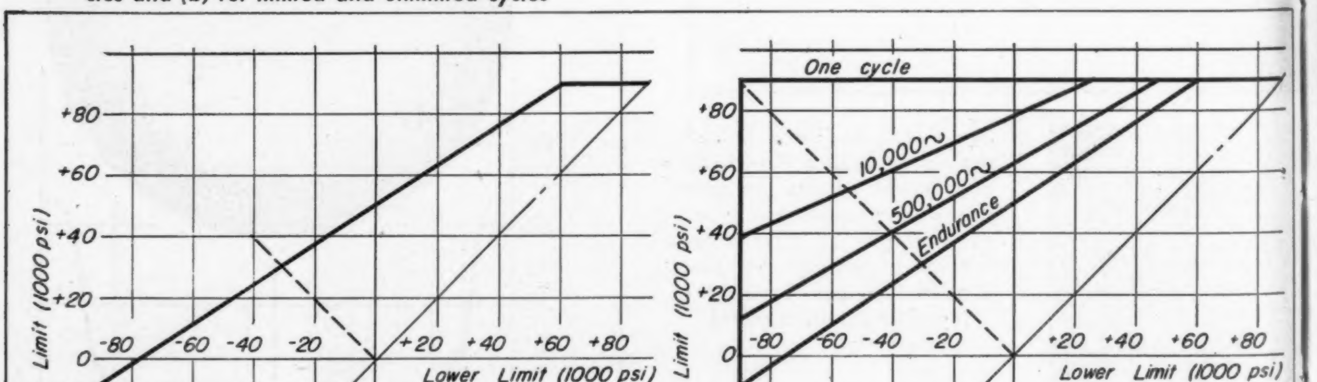
Endurance Limit Raised 115 Per Cent

A remarkable example of this use has been reported by Horger and Lipson[1] who showed that the endurance limit of automotive rear axles, as measured in a rotating beam machine, was raised from 20,000 psi to 43,000 psi by shotpeening. In this process a relatively shallow surface layer, about 1/64-inch deep, is given a trapped compressive stress by peening with hard steel shot. The use of the same shotpeening process to increase the endurance of coil springs, stressed in torsion, is standard practice in the automotive industry, for small valve springs as well as for large suspension springs.

It is interesting to note that one of the big three automobile manufacturers heat treats all rear axles to produce a compressive trapped stress near the surface by a different process. This process depends on the fact that, with a shallow-hardening steel, quenched drastically, the decrease of temperature near the center of the axle is too slow to produce a metallurgical transformation. However, near the surface, to

[1] References are tabulated at end of article

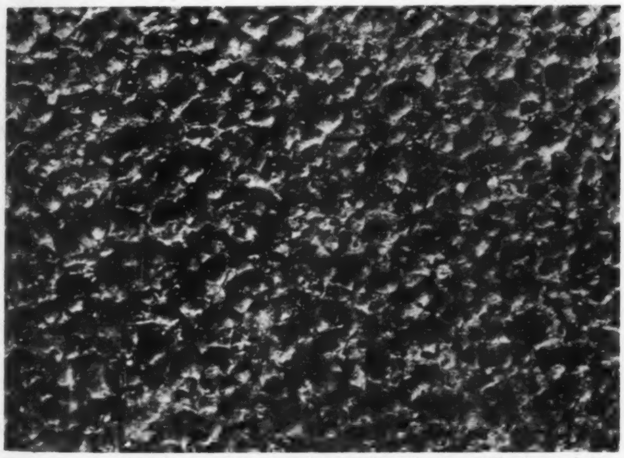
Fig. 4—Modified Goodman diagrams (a) for unlimited cycles and (b) for limited and unlimited cycles



a depth of somewhat over ⅛-inch, the temperature drops fast enough to induce hardening, *Fig.* 3. The transformation which produces hardness also produces an increase of volume, so that the surface layer, if it were not restrained, would expand. Expansion is prevented because the surface is tightly bonded to the core and a high compressive stress is the result of the inhibited expansion.

A similar result could of course have been obtained by carburizing. Although the good results of carburizing are usually ascribed to a hard, wear resistant skin on a tough core, the theory seems justified that carburizing works mainly by producing trapped stresses.

ENDURANCE FACTORS: To gain a better understanding of the fact that compressive trapped stresses increase endurance against load reversals, it must be considered that endurance is a function of both stress range and stress level. A stress cycle can be defined by its lower and upper limit. Since the upper and lower limit can be either tensile or compressive it is necessary to distinguish them by algebraic signs, plus for tension and minus for compression, and to remember that by "lower" is meant the algebraically lower stress. In other words, a stress cycle extending from 30,000 psi compression to 20,000 psi tension

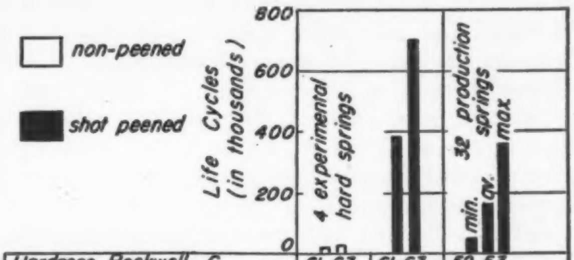


Photo, courtesy American Wheelabrator & Equipment Co.

Fig. 5—Surface view of shot-peened steel at a magnification of approximately seven times actual size

will have the lower limit minus 30,000 psi and the upper limit plus 20,000 psi.

It is a fact established by experience that for most materials the permissible stress range—difference between upper and lower limit of the cycles—is higher when the stresses are compressive than when they are tensile. One old rule of thumb states that compressive stresses are 5/6 as dangerous as tensile stresses; actually, it is believed that the difference is often greater than indicated by this rule. A practical application can be seen in the leaf springs of many cars, which are shaped in such a manner that the neutral axis is closer to the tension side, thus giving lower tensile stresses at the expense of somewhat higher compressive stresses. The shape of longbows and of skis—flat on the tension side and convex on the compression side—is evidence that old-



Hardness Rockwell C	61-63	61-63	52-53
Cold pressed	no	no	yes
Peening intensity	—	—	.012 A
Hot pressed 50 times at	300°F	300°F	575°F
Peening intensity	—	.018 A	—
Draw	no	no	to hardness

Operations arranged in sequence

Fig. 6—Effect of shot peening on fatigue durability of brittle springs compared with softer production springs

time craftsmen had reached the same conclusions on the basis of long experience.

MODIFIED GOODMAN DIAGRAM: The modified Goodman diagram, *Fig.* 4, is one good way to gain an overall view of the various combinations of stress limits which can be used without leading to danger. Such a diagram is obtained by plotting the upper limit of the stress cycles as ordinate over the lower limit as abscissa. A curve of equally dangerous stress cycles results.

Interpreting the Diagram

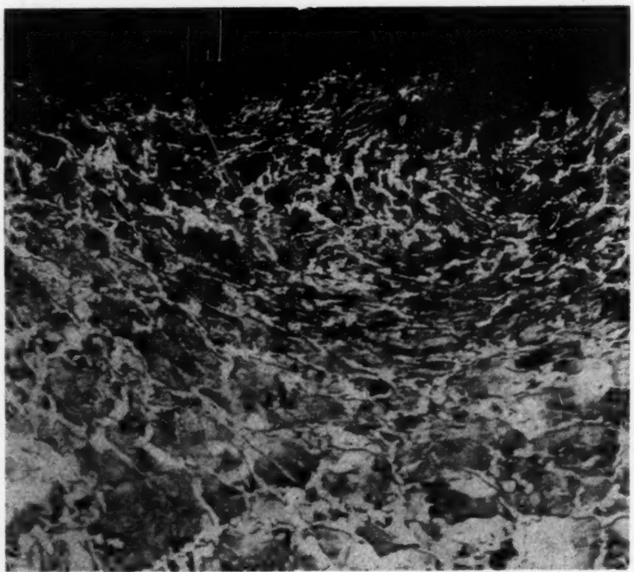
Fig. 4*a* shows such a curve for the endurance limits of a particular steel. For zero lower limit the upper is 50,000 psi, meaning that the endurance limit for pulsating stresses varying from zero to tensile is 50,000 psi. Similarly the endurance limit for pulsating stresses varying from zero to compression is shown at the intersection of the diagram line with the horizontal axis, about 75,000 psi compression. The generally quoted endurance limit for fully reversed stresses is found where upper and lower limit are numerically equal, at the intersection of the diagram line with a 45-degree diagonal sloping upward to the left. It is shown as 30,000 psi, corresponding to a usable stress range of 60,000 psi.

Stress ranges corresponding to each point on the diagram may be visually indicated by vertical arrows extending down from the upper limit to the 45° diagonal sloping upward to the right. It will be seen that the usable stress ranges increase from right to left in the diagram, meaning that the fluctuating stress can safely be increased if the static stress is made more compressive or less tensile. The important point is that this static stress need not be a load stress: It can be a trapped stress. Compressive trapped stresses increase the permissible stress range in fatigue. This is true, as shown by experience with springs, for torsion as well as for tension and compression.

For limited life the incentive to use trapped com-

pressive stresses becomes even greater, as indicated by *Fig. 4b*. Here the safe stress cycles are shown for certain limited numbers of cycles as well as for endurance and for single cycles. For single cycles the limits are given by the yield strengths in tension and compression, which are shown as 90,000 psi. In the case of single cycles, failure will occur as set rather than as fracture. For larger numbers of cycles, failure may either be set—if the combined trapped stresses and load stresses exceed the yield strength in tension or compression—or it may be fracture if the stresses exceed the safe limits indicated by the slanting lines of the diagram.

For other materials, or for steel of different hardness, or for a different surface condition of the test piece, a different diagram would be obtained. The diagrams given here are intended as a qualitative indication of well-established general behavior, not as exact design data. It is, of course, highly improbable that series of test points would fall exactly on the lines which are shown; the natural scatter of fatigue test points would be sufficient to prevent this. It is also likely that there is a transition region in which failure may be either by fracture or by set, depending in part on how small a set is considered permissible. This transition region would round off the sharp corners shown in the diagrams. But in view of present ignorance of the exact mechanism of fatigue, and of the lack of fatigue experiments with various limits and test conditions, it is better to get the general trends firmly established in the mind by simple lines than to check whether these lines are straight or perhaps parabolic.



Photo, courtesy American Wheelabrator & Equipment Co.

Fig. 7—Cross section of shot-peened steel at a magnification of 200, showing compressively stressed skin

OTHER EFFECTS: The endurance diagram, *Fig. 4a*, shows an increase of stress range from 60,000 psi for fully reversed stresses to a little over 80,000 psi at the yield strength in compression. This increase can be obtained by superimposing a trapped compression stress upon the load stress in a rotating beam test, but no matter how liberal the interpretation, it is obviously not sufficient to explain the test data of Horger and Lipson, which showed that shotpeening increased the safe fatigue load more than twofold. Surface improvement, workhardening, and increased ductility must be considered to obtain an adequate explanation.

Surface improvement is easily visualized as an ironing out of the multiple small defects in the as-forged surface of the axles by the overlapping peening marks left by the shot, *Fig.* 5. Similar results are obtained by surface rolling, burnishing, or polishing.

Cold Deformation Effects

Workhardening, or strainhardening, is not as easily pictured, but must be accepted as an experimental fact. It is well established that both yield strength and fatigue properties of steel and other materials are increased by cold deformation. The physical properties of cold-rolled steel are higher than those of hot-rolled steel. Hard-drawn spring wire obtains all its hardness and strength by cold drawing, and brass can be manufactured in various tempers, depending on the amount of cold reduction. The true tensile test diagram, in which stresses are calculated on the actual reduced section instead of the original section, shows strain hardening as the basic property it is. This effect is quite separate from, and in addition to, the effect of trapped stresses. One can workharden and offset the gain by introducing unfavorable trapped stresses, or one can introduce trapped stresses and their effect by controlled heating and cooling without any workhardening. Shotpeening, as a cold working process, introduces work hardening and trapped stresses together.

Local Yielding Distributes Load

Ductility: Finally, the trapped compressive stress increases ductility and thereby enables small areas of imperfection to yield and pass their share of the load to stronger neighboring areas without opening a crack which would form a nucleus for stress concentration and progressive fatigue failure. Plastic flow occurs when the shear stress at a point exceeds a certain value. Fracture occurs when the tensile stress at the point is excessive. Assuming that a point is in danger of showing a crack under the effect of high tensile stress, this danger will be decreased if a compressive stress can be deducted. Furthermore, if compressive stress in a direction at right angles to the highest tensile is introduced, the two combine to form a shear stress which may result in plastic flow, by which the load can be passed on to a neighboring area.

It is well known that a deep cup can be drawn from a flat sheet, while it is impossible to draw a long flange around a hole in a flat sheet. The difference between the two is this: When drawing a cup, the metal is drawn in from the outside, produc-

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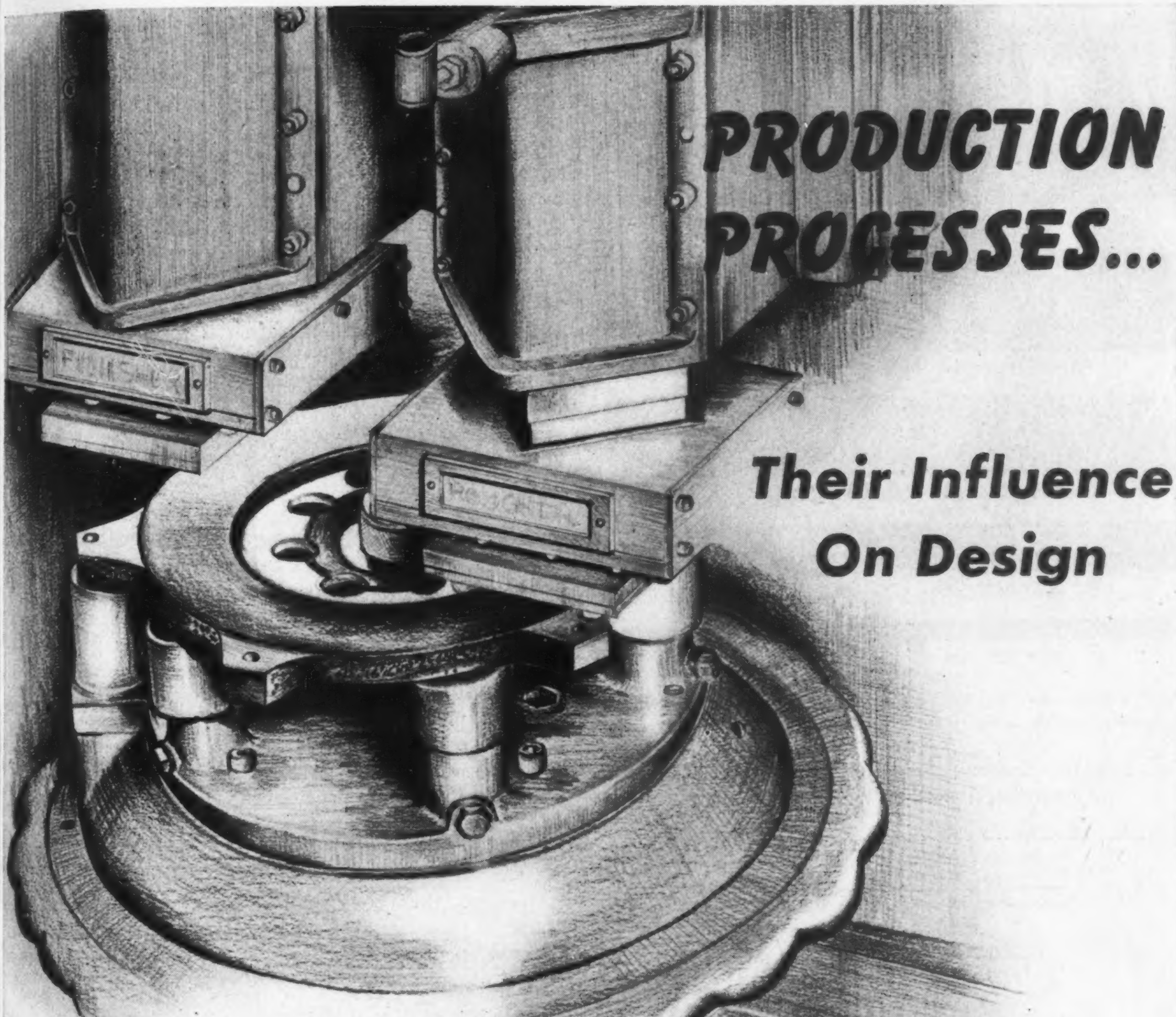


PRODUCTION PROCESSES...

Their Influence On Design

By Roger W. Bolz
Associate Editor, Machine Design

Part XXXV–Superfinishing

REPRESENTING the ultimate in present-day production methods, in terms of increasing refinement of surface finish, is that process commonly termed Superfinishing. As with the lapping process, Superfinishing makes a complete break with previous metal-removal methods, being used only for obtaining the finest surface finish and improved geometrical accuracy.

Although the honing methods discussed in the previous article apparently afford very similar results, research has shown some basic differences are present. Because finishing is done at slow speeds and low pressures, all tendencies toward heating or burnishing are obviated. Owing to the fact that a large-area bonded abrasive of precisely controlled characteristics is employed, minute projections, waviness, etc., are removed and a clean-cut, undisturbed crystalline surface structure is produced.

A large- area bonded-abrasive tool operated with multidirectional travel, the stone is worn

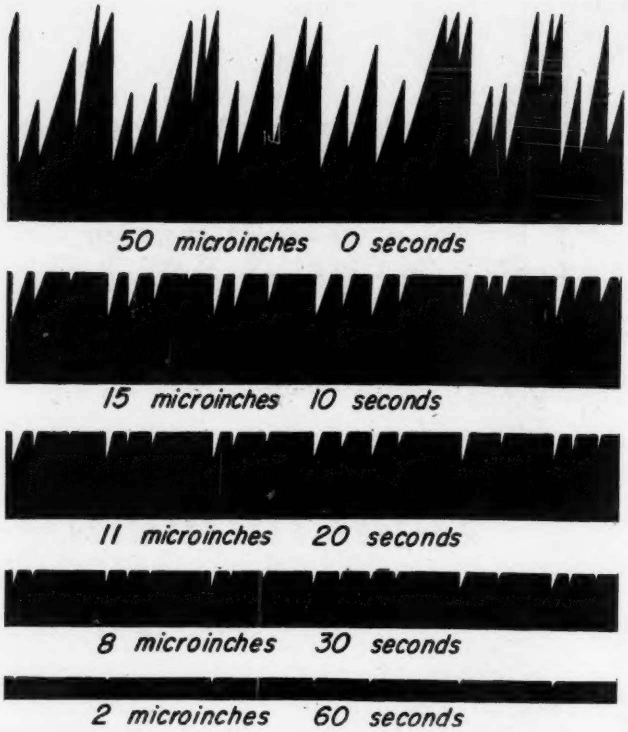
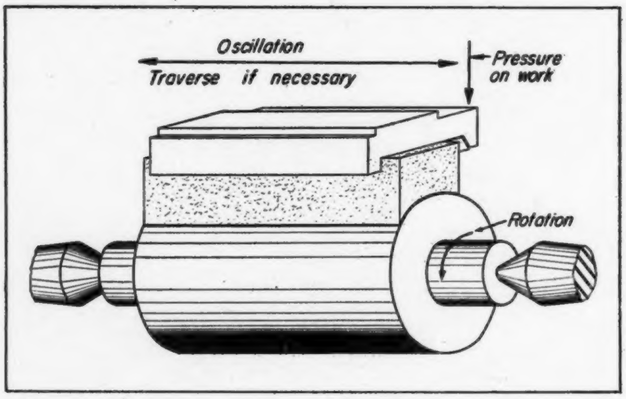


Fig. 1—Above—Diagram made from actual crankshaft operations showing ground profile to finished surface

Fig. 2—Below—Schematic diagram showing arrangement and operation for finishing cylindrical pieces



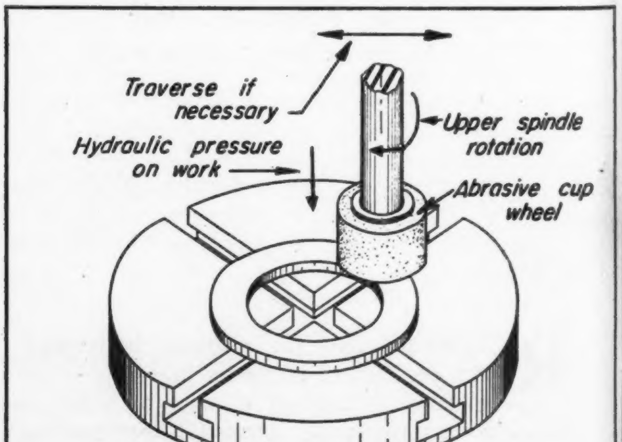
automatically to a true curvature or flat, as the case may be, and thus acts as a master shape to correct the geometry of the work surface. Actually, only irregularities, projections and inconsistencies over and above the desired true geometrical profile are removed, *Fig.* 1, a characteristic not found in other methods. In this respect the process resembles hand lapping to a metal master-shape, but is much faster and can never "charge" a surface as loose abrasive lapping may do. Like lapping, there is no real stock removal in a sense, the processing merely refines the surface finish and increases the true bearing area. Actual dimensional change through removal of high spots seldom exceeds 0.0001-inch in most average production work.

Unique among processing methods, Superfinishing will remove the roughness and irregularities left by previous operations, produce any reasonably selected smoothness, then automatically cease cutting action. A bonded-abrasive stick, properly dressed, is used for cylindrical or cone shapes, *Fig.* 2, while a bonded cup wheel is used for spherical or flat work, *Fig.* 3. Large area is used; in cylindrical work, for instance, the stone is 60 to 75 per cent of the part diameter in width and often the full length of the surface to be refined. Abrasive speed seldom exceeds 80 fpm, with an average of 55 fpm, and the abrasive is held in contact with the work under a flexible pressure of 10 to 40 psi. Usual work speed is about 50 to 60 fpm and operation is carried out under a flood of low-viscosity lubricant rather than a plain coolant.

As the stone is applied to a rough surface, it contacts only the high points or ridges on waviness crests. Here the unit pressure becomes high owing to the small-area contact, and the stone easily penetrates a lubricant of any viscosity to begin abrading the peaks. A stone of the correct character breaks down somewhat, continually exposing new, sharp grits and is virtually self-dressing. As the peaks are reduced and the surface improves in smoothness, unit pressure decreases owing to increased contact. As this takes place, cutting and dressing decreases, the stone surface dulls or glazes progressively, and finally, as the perfection in shape of both stone face and work becomes great enough, pressure sufficient to force the grit points through the film of the lubricant is not available and further removal of material ceases.

First conceived in 1934 by D. A. Wallace of the Chrysler Corp., the process has been in a continuous state of development ever since. While there are several general sources of wear, through the results of comprehensive research it is becoming generally recognized that the welding together and breaking apart of minute high spots of rubbing surfaces is the major cause of metallic wear. Because of this

Fig. 3—Below—Schematic diagram showing principles employed in finishing flat surfaces



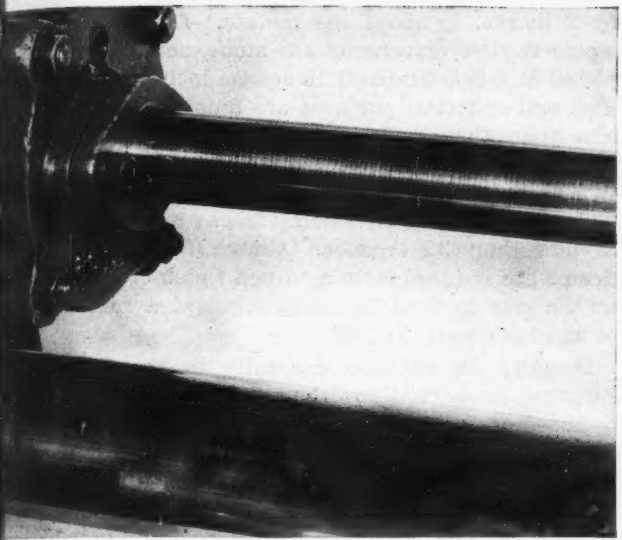


Fig. 4—Superfinished shafts, the smaller of which operates through nonmetallic packing and the larger through a cast-iron bore. Almost no wear has been found after seven years of operation

fact, it becomes imperative that projecting defects be reduced as much as practicable. Hence the major purpose of Superfinishing.

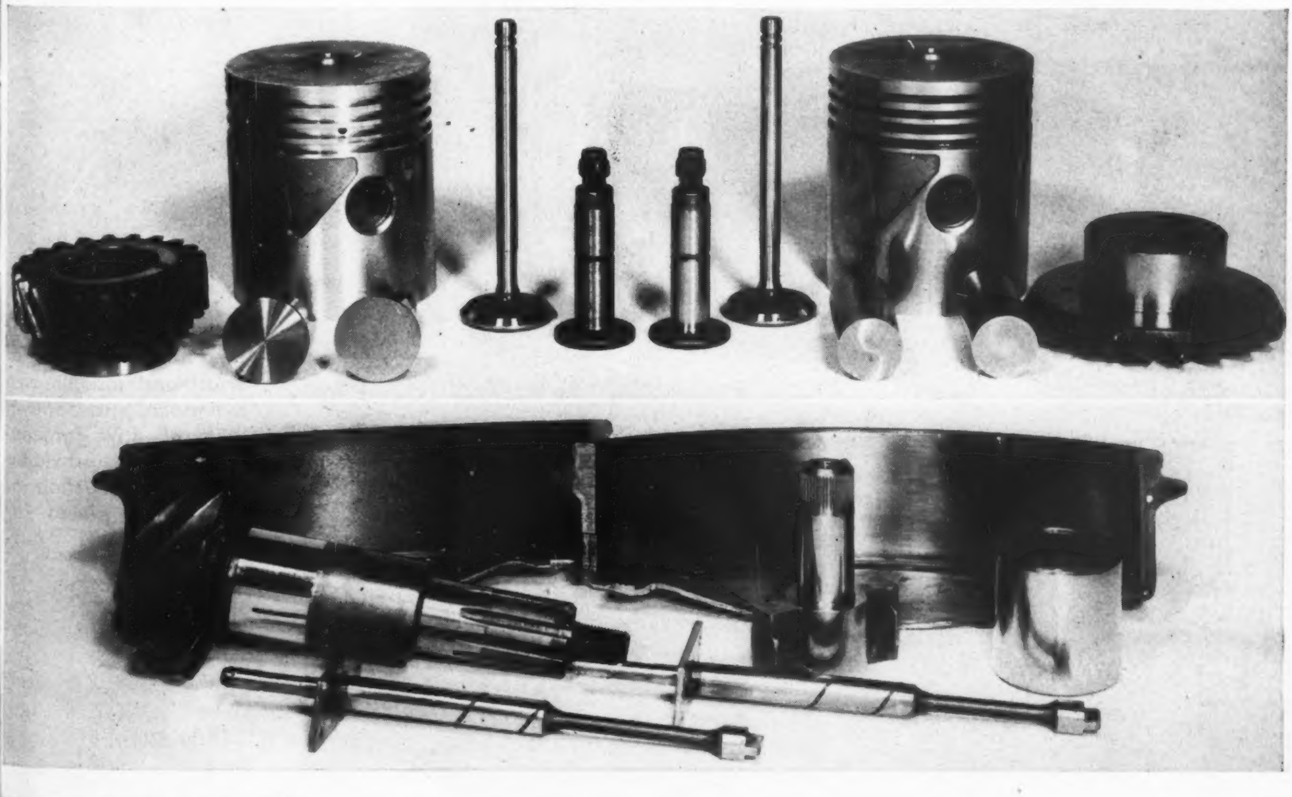
Any metallic surface that rubs upon another, and certainly those parts that must operate with an absolute minimum of clearance or under heavy loadings, should be considered for Superfinishing. If such a part requires hardening, the need is more pronounced; because of heat produced in grinding, the surface hardness is often altered to some extent and removal of this fragmented layer is beneficial. One of the most important uses is on parts that operate within oil seals or packing glands. Maximum possible smoothness prolongs the life and effectiveness of such units immeasurably, ***Fig.*** **4**.

While Superfinishing is primarily *not* a dimension creating process, it is obvious that in generating geometrical accuracy by removal of high spots, some small decrease in apparent dimensions will take place. This may amount to 0.0001 to 0.0002-inch on diameter as an average. A range of surface finishes from a mirror finish to about 30 microinches rms can be produced. Almost any reasonable scratch pattern is possible, ranging from none at all to intentional cross-hatch patterns.

Representative of parts which are usually Superfinished are crank pins, clutch plates, valve stems, piston pins, pistons, piston rods, tappet heads, tappet bodies, valve seats, brake drums, cylinder bores, bearing bores, etc., ***Fig.*** **5**. Certain limitations, however, are present as to the shape of the parts which can be superfinished readily and economically. Surfaces to be refined must be those of symmetrical sections such as external cylinders, large internal cylinders, flats, spheres, or cones. Flat parts should have a reasonably round outside dimension. With the proper abrasive stone, fluted shapes, shafts with keyways, or other recesses can be handled, ***Fig.*** **6**.

In the present state of development, a variety of both general-purpose and high-production machines are available for Superfinishing almost any reasonably symmetrical surface, ***Figs.*** **7 and 8**. Cylindrical surfaces ranging from 1/8-inch diameter up to as large as 14 feet can be processed. General purpose Superfinishers, however, presently can handle parts up to

Fig. 5—Below—A group of representative parts which employ Superfinished surfaces



about 4½ inches in diameter by 36 inches in length. Range of dimensions for circular flat surfaces is from about ½-inch to the capacity of the largest machine (a boring mill, for instance) upon which a Superfinishing attachment can be mounted. Spherical sections may range from about ½-inch diameter to about 4 inches on present equipment.

Time consumed in Superfinishing is extremely short and production consequently can be high, *Fig.* 8. Small cylindrical surfaces up to about ½-inch in diameter and 1-inch in length are finished to 3 microinches rms in 30 to 45 seconds. Those up to 2 inches by 2 inches, in about one minute. Larger surfaces, which require traverse of the stone, usually are completed at a rate of about 10 square inches per minute. Flat and spherical surfaces are finished in somewhat less time than cylindrical. Tappet heads, for instance, are usually corrected in geometry and finished to less than 2 microinches in a maximum of 30 seconds, *Fig.* 9. Cast iron pump faces are often finished in less than 20 seconds. Clutch faces and brake drums are reduced from a turned finish of 200 microinches rms to 7 to 15 microinches at a rate of 100 or more per hour, *Fig.* 10.

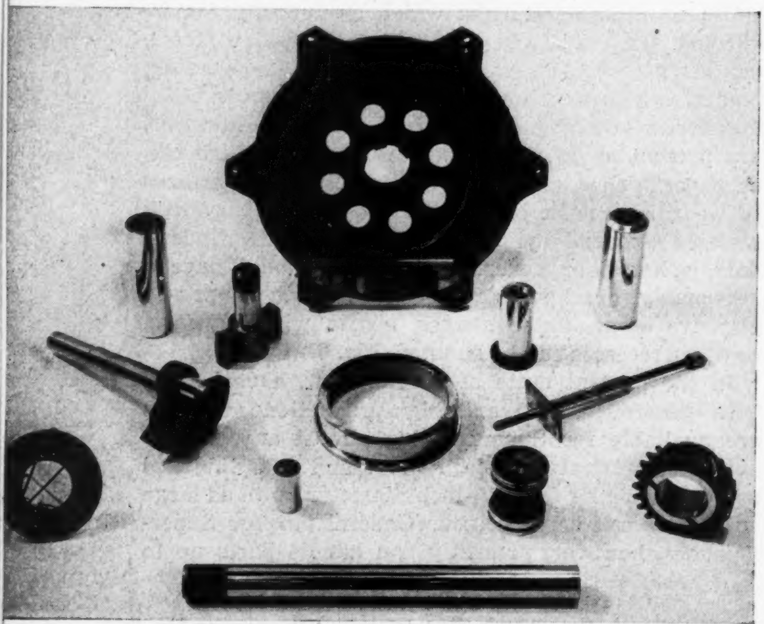


Fig. 6—Above—Group of flat, grooved and recessed parts which have been Superfinished

DESIGN: As outlined generally in the foregoing, surfaces considered for Superfinishing must usually be those of uniform symmetrical sections such as cylinders, cones, spheres, or flats. Flat surfaces should be designed so as to eliminate the necessity for finishing projections and other features which create a noncircular outside boundary. Such portions should be relieved well below the finished surface.

Complications such as shoulders, ports, flutes, slots, oil grooves, keyways, blind bores, etc., are, of course, usually essential but these features often serve to prevent ready access for Superfinishing. With the proper width of abrasive stone, flutes, keyways, ports, etc., can be spanned and the main surface finished. Blind-end bores, whether Superfinished on an internal or external cylindrical surface, should provide an undercut or relief at least a few thousandths larger than the finished surface, *Fig.* 11, and about 1/16 to ⅛-inch in length.

For most economical Superfinishing the preliminary metal-removal operations should remove the bulk of the material, allowing only for the minute dimensional change which may take place. A reasonably accurate rule which may be followed in ascertaining the average change which may be expected is that 0.0001-inch will be removed on the diameter for each

Fig. 7 — Left — Twelve-station Superfinisher for high production of small and medium-size cylindrical parts. Shown with roll drive for centerless parts, providing average production of 600 to 700 pieces /hr

10 microinches rms reduction in surface roughness. On flat surfaces this figure would be halved.

Production economy in Superfinishing depends greatly upon the degree of roughness left by preceding operations. It is seldom economical, for instance, to attempt to obtain a surface of 3 microinches or less from a grind rougher than 20 to 25 microinches; 10 to 20 microinches is the most desirable. Degree of accuracy obtained in finishing also is dependent upon the preliminary operations. Dimensional accuracy and uniformity should be held as close as possible in the preparatory operations.

Materials: Materials which can be Superfinished include practically all the ferrous and nonferrous metals and alloys and also many nonmetallics such as molded friction materials, glass, wood, fiber, etc.

Preparatory operations best suited for different materials will vary with the material used. Cast iron parts such as brake drums, pistons or flywheels can be either turned or ground. Turned finish should not range over 150 to 200 microinches ordinarily. For soft-steel parts grinding is preferable as a rule. Hardened steel parts such as tappets, pins, gears, spindles, etc., require a ground finish. Nonferrous materials can be turned or ground prior to Superfinishing,

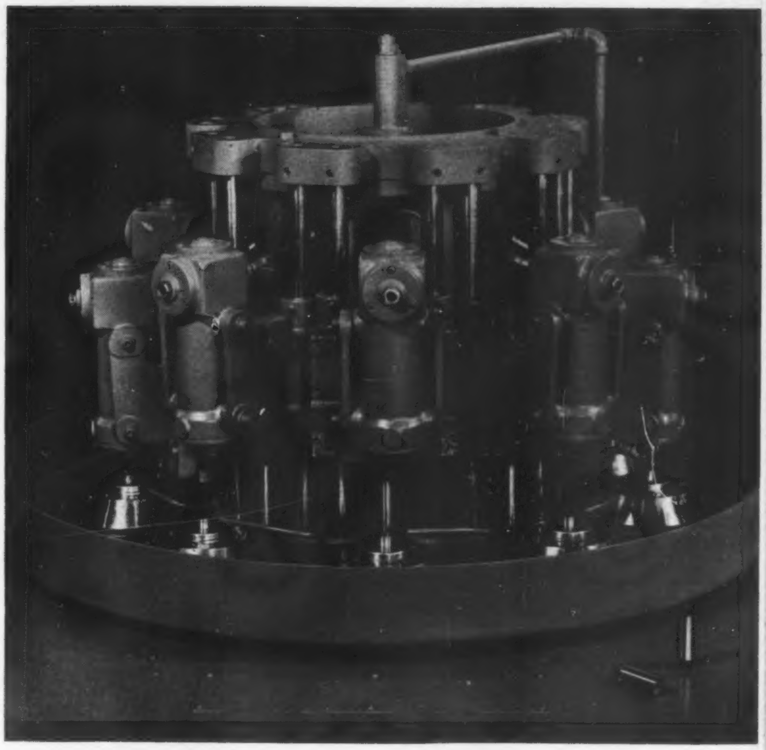
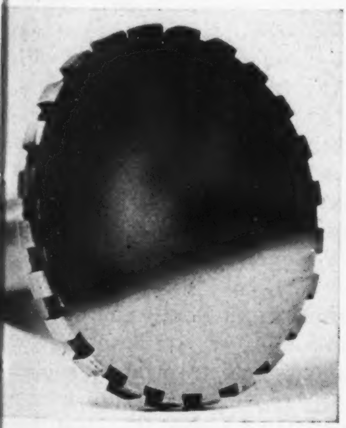


Fig. 8—Above Right—Nine-spindle machine for flat and spherical work. Surfaces reduced to about 2 microinches at average rate of 800 to 900 pieces /hr

Fig. 9—Below—An aviation tappet head finished to approximately 2 microinches or less



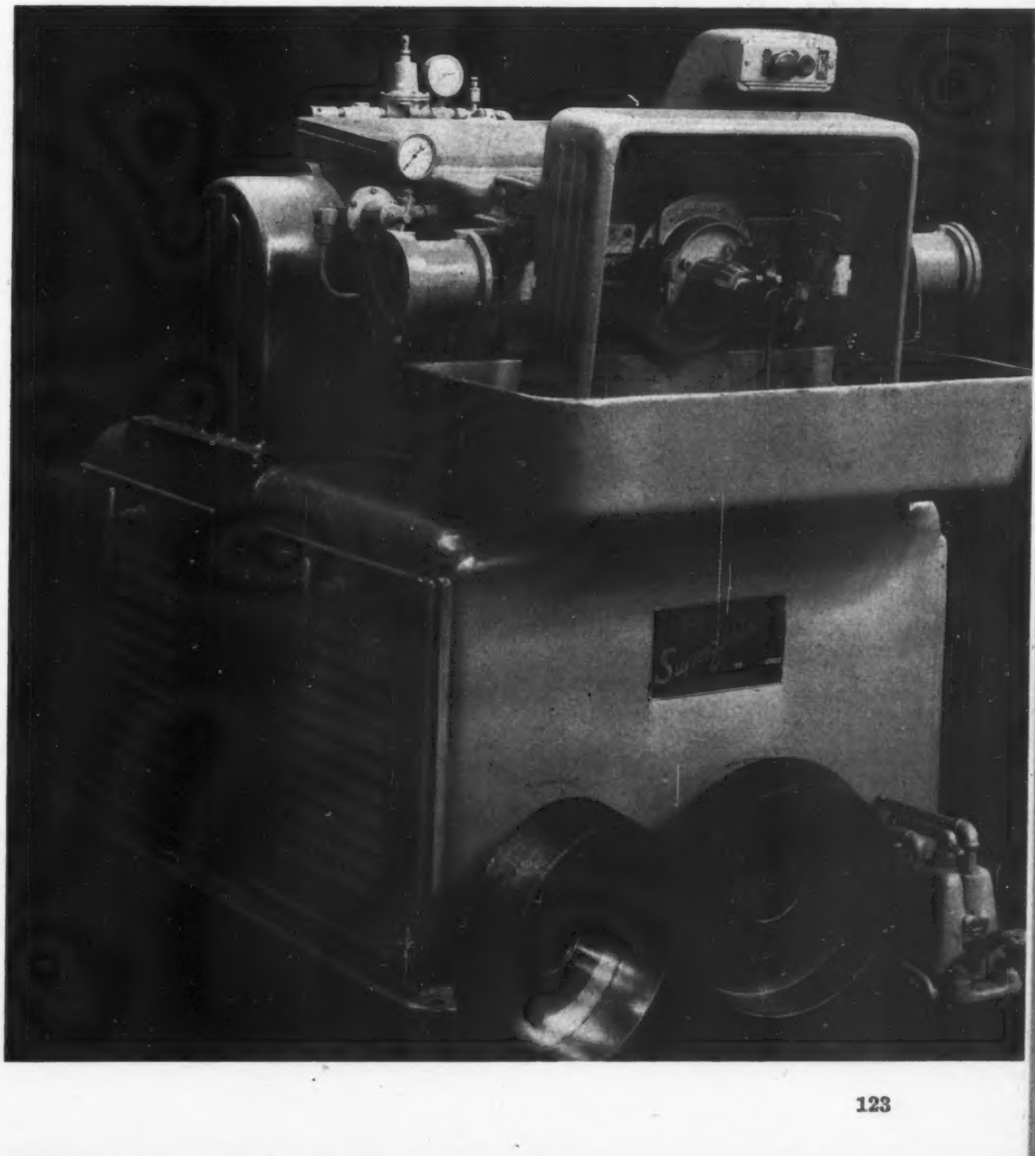


Fig. 10 — Right — Special brake drum Superfinisher reduces a 200 microinch turned surface to 7 to 15 at a rate of 120 or more drums per hour

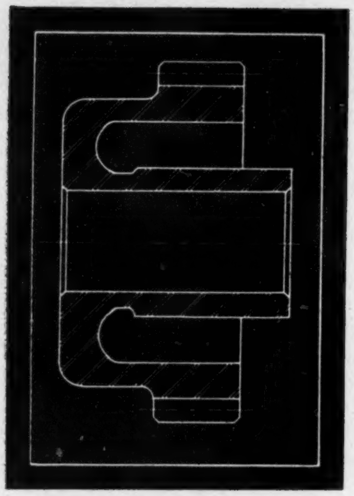


Fig. 11 — Left — Aircraft engine reduction drive pinion presents a rather difficult grinding finishing problem. Relief is a necessity at the blind end of the bore

Fig. 12 — Below — Range of finishes possible from cross directional scratch pattern to a scratchless mirror finish

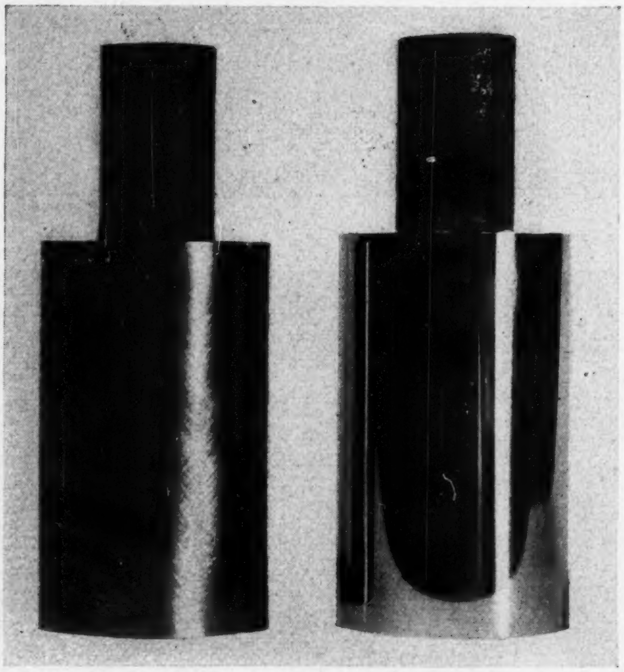


Fig. 13—Below—An outboard motor crankshaft Superfinished to a mirror smoothness

but the primary requisite is, regardless of the preliminary processing operation, that surface roughness be uniform.

TOLERANCES: The primary purpose of the Superfinishing process is the creation or development of a geometrically true unworked material surface free from fragmented, amorphous or smear particles. Not being specifically a dimension creating process, true Superfinishing does not completely remove gross out-of-roundness, taper conditions, deviations from true straightness or misorientation. Although dimensional irregularities of some magnitude can be corrected, provided sufficient time and successive operations can be utilized, maximum efficiency in production requires that the desired uniformity and accuracy as to location, straightness, out-of-roundness, taper variations from piece to piece, etc., be provided by the preliminary operations.

Limits Depend on Previous Operations

The only dimensional change or action incurred rests primarily with the removal of high spots, waviness, and other defects in reducing the curvature or flat to a reasonably true geometric surface. Thus the dimension resulting from a Superfinishing operation will depend upon that of the previous operation and the surface roughness it produces. Dimensional change to be expected has been covered in the foregoing. Actual tolerances on average production runs of parts normally can be held within the same dimensional limits produced by the previous operation. Where desirable, and providing preliminary operations can be properly controlled, dimensional accuracy can be held within somewhat closer limits than those normally produced by the preceding process.

As noted previously, any reasonable depth of scratch pattern can be produced from virtually none to about 30 microinches rms, *Fig.* 12. Where a scratch pattern is deemed advisable, an intentional cross-hatch finish can be produced. Though no hard or fast rule is available as to the desirability or usage of scratch patterns, the favor most often lies with the smooth surface ranging from 1 to 4 microinches, *Fig.* 13. Where scratch patterns are desirable, however, the recommended limit seldom ranges beyond 4 to 12 microinches rms. Practical experience has established the fact that a cross-hatch pattern is equally as satisfactory as a random, multidirectional one and machines are no longer made for producing random patterns.

Normally, a finish ranging from 2 to 3 microinches is obtained in one operation of one minute or less duration. It is seldom economical to produce such a surface from a grind rougher than 20 to 25 microinches. Rougher surfaces can be used to start but the finish will range around 4 to 7 on the finished part. A turned surface on cast iron of about 200 microinches rms can be finished to 10 to 15 microinches in this time. Where design demands, surface finish less than 1 microinch can be attained without excessive expense.

Generous cooperation of the Gisholt Machine Co. in the preparation of this article is acknowledged with much appreciation.

The Engineering Department

its function and organization

By George T. Trundle Jr.
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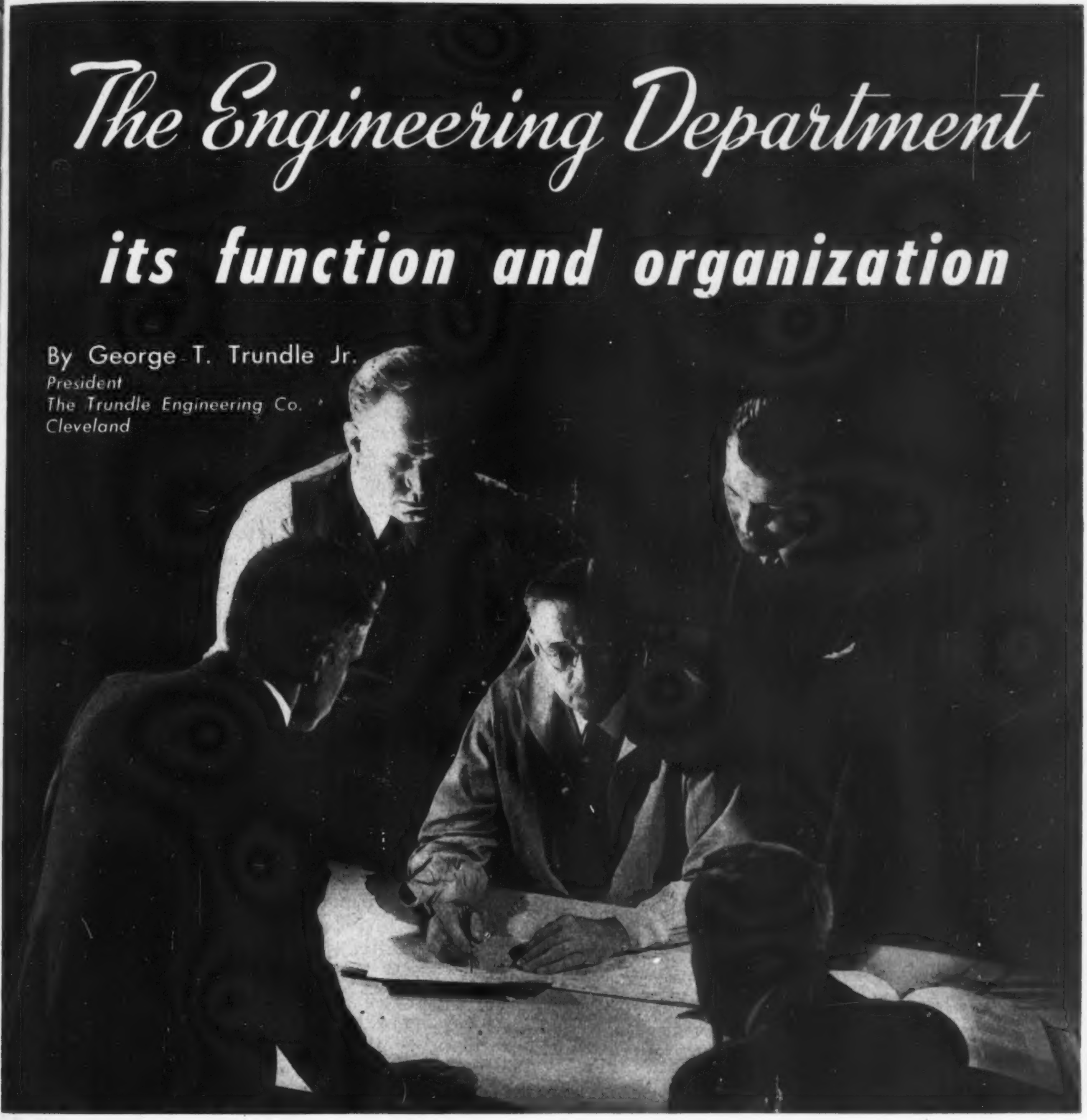


IN A LARGE company, departmentalization and definition of the functions of each department tend to work themselves out rather naturally because of the sheer size of the organization. But in small and medium-sized companies, the problem of departmentalization and assignment of functions often becomes more difficult because of natural overlapping, and because of the closeness of personal relationships of all of the people involved in the management of the enterprise.

This is particularly true in connection with the engineering department. In altogether too many cases, among companies that are small by comparison to our great national corporations, engineering, which includes design and many other functions, is in a sort of "betwixt and between" position where it doesn't know exactly what it is supposed to cover.

THE ENGINEERING FUNCTION: Before the responsibilities of an engineering department can be ascertained, it is necessary, first of all, to determine the functions to be performed by this department. These remain the same whether a company is large or small. They arise from two sources, as follows:

1. Ideas that originate *outside* the engineering department from customers, from salesmen, or from sales-minded management
2. Ideas that originate *inside* the department, in the minds of creative designers and engineers with an inventive turn of mind, who conceive something they think might enable the company to do a

more efficient production job, or to turn out something that might better meet today's desires on the part of the customer.

Ideas that Originate Outside the Department: As a matter of standard practice, management brings to the engineering department ideas based upon knowledge gained from contact with customers and prospective customers. It is then the function of the engineering department to translate such ideas into design, in sufficient detail to enable management to determine whether they will meet requirements as to customer acceptance and production costs.

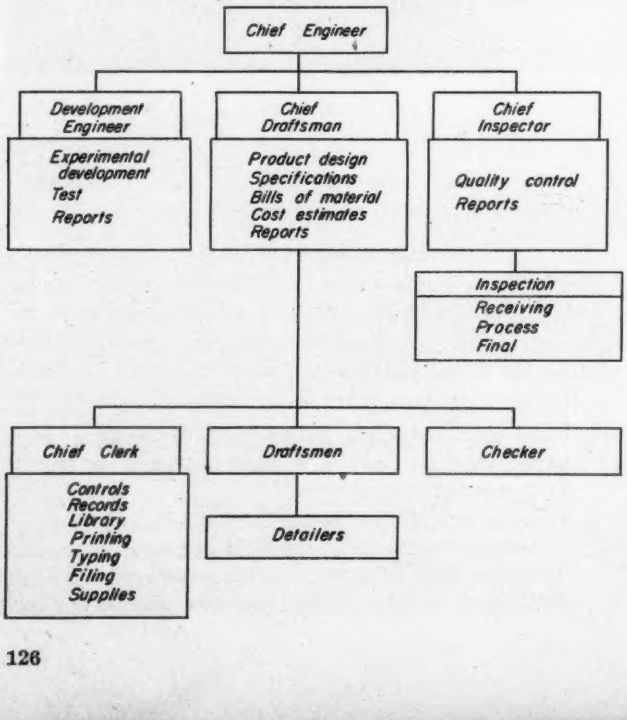
Suppose a company is in the business of making custom-built machines. In that case, management may get from its sales department, or from a particular customer, a request for a machine that will perform a specific function. There will be definite specifications as to the quantity of production desired, the accuracy of parts, the production cost of the machine, etc. Here it becomes the responsibility of the engineering department to evolve a design and submit it, not only to management but, to the particular customer for suggestions and approval.

If a company is making a standard machine or product, the engineering department may receive an order from top management to redesign that machine or product in the light of questions such as improved performance, better appearance, reduction in maintenance cost, reduction in manufacturing cost, improvement in parts standardization, and better utilization of materials. It is then up to the engineering department to turn out a new design to submit to management along with claims as to the extent to which the new design will help effect the desired objectives.

These three illustrations are typical of the functions of an engineering department with respect to ideas that originate outside the department.

Ideas that Originate Inside the Department: But the personnel of an engineering department are not supposed to be purely passive people who use their ingenuity only to the extent called upon by requests, or demands, from the outside. Any up-and-coming engineering department has ideas of its own.

Fig. 1—Organization chart for small companies in which engineering is headed by a chief engineer



In the normal course of events, someone in an engineering department develops an idea for a better machine. It then becomes the responsibility of the department to translate this idea into a practical design. This means preparing the design in sufficient detail to bring to management for suggestions and approval. This is the research and experimental phase of the engineering department; which is just as important as is the function of developing suggestions and ideas that come to the department from the customer or from the management.

Most Developments Originate in Department

In fact, in the history of American industry, the greatest technological advancement has been made by the internal personnel of engineering departments who have conceived original ideas and proved to management that those ideas are workable, profitable, and of benefit to the customer.

A Staff Function: In view of the foregoing, it is readily understood why engineering is a staff function; whether it be in a large, medium, or small company; whether reports are made to the president, executive vice president, works manager, or superintendent.

The man in charge of the engineering function of a company is what might be called a two-way traffic man for creative ideas. The ideas that come from the *outside* must pass through him in order to be translated into creative accomplishment within his department. Likewise, the ideas that come from *inside* his own department must pass through him if management is to recognize their possibilities and take the steps that will enable them to be worked out for the benefit of the company and its customers.

Usually, in a small or medium-sized company, the head of the engineering department is called the chief engineer, or the chief draftsman. The title makes little difference. Of course such a man must have the technical assistants he needs to fulfill his function.

Where products unrelated to the general line of the company are involved, or where there is a case requiring special technical knowledge—such as, let us say, electricity or hydraulics—it is good practice for the head of a department to have an assistant in charge of these particular special fields.

In any good engineering department there should be one or more engineers capable of assisting the sales department in getting business, assisting the customer in getting a machine in operation, etc.

In many cases, especially in the medium-sized and small companies, plant inspection comes under the engineering department. Certainly, close co-operation must be maintained between the engineering and inspection functions in order to assure quality and performance of product.

The type of organization which is practicable for most small companies is indicated in *Fig.* 1. This shows engineering headed up by a chief engineer.

George T. Trundle, Jr., having had wide experience in design and development work as well as manufacturing and management responsibilities, writes with the authority of 45 years of background in machinery manufacturing plants. He served as designer for both the Peerless Motor Car Co. and the Royal Motor Car Co. He was an experimental engineer for the National Adding Machine Co., and chief engineer of the American Multigraph Co. During the first World War he was chairman of the Fuse Manufacturers Association, aiding in the manufacture of munitions for the government. For the purpose of rendering consulting service to industry for management, sales, production, and design problems, he organized the Trundle Engineering Co. in 1919.

The line of responsibility follows down through the chief draftsman, through the regular channels of preparing drawings and the performance of the customary operations involved. On the left, in this chart, is the development engineer—on the right, the chief inspector. No allowance has been made in this chart for various assistants that may be needed, depending upon the type of engineering.

In some cases, in either small or medium-sized companies, the position of chief engineer may be eliminated because it is occupied by one of the executives of the company. It might even be the president himself, a vice president, the works manager, or superintendent. In any case, the chart of organization is naturally headed by the executive in question, as indicated in *Fig.* 2.

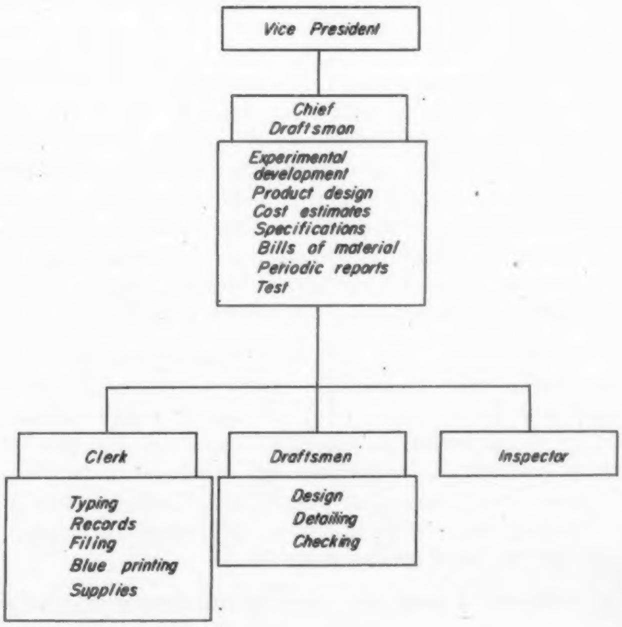
This chart shows an organization parallel to that in *Fig.* 1, but in which the top officer of a company assumes full charge of engineering. The next man in line is called a chief draftsman. The development engineer has been eliminated and this responsibility has been delegated to the chief draftsman. Also the Inspector reports direct to the chief draftsman.

Follow Through: No matter whether an idea coming to the engineering department originates from the outside or from the inside, it has to be followed through in exactly the same way. The first step is a design to be submitted to management. If management approves the design, then detail drawings must be made of each part, and specifications prepared from which the machine or product will be built; either in the general shop or in a separate department set up for experimental and research work. There are many steps involved in transforming a project into production. Each of these has its own particular importance in the ultimate success of the project and the major points follow:

Preliminary Design: For the sake of illustration, consideration will be given to the development of an idea that originates from the sales department for a new product with rather careful specifications covering all phases of design and cost.

The first step to be followed is to develop a rough draft of the idea in order to visualize the layout of the entire project. Depending upon the size of the plant, this function may be performed by the chief draftsman or design engineer. This first step is of utmost importance in presenting a clear picture of the idea, and unless carefully done, all of the following steps will be excessively costly. It is the key to economical operation of the engineering department since the person accomplishing this first creative effort must make a rough draft sufficiently clear to be readily understood through all successive steps and must at all times give consideration to every detail

Fig. 2—In this chart the position of chief engineer is held by a vice president in charge of engineering. The chief draftsman then is directly responsible to this executive for all engineering activities



of the specifications which initiated the project. Failure to do so at this time creates confusion in the subsequent steps.

LAYOUT: The second step in the development of the project is that of layout. This is done by a draftsman or layout man and consists primarily of rough dimensioning the previous visualization of the layout for the benefit of the detailers. In this step it is important that any mechanical interference be avoided, and at this point economy of manufacture and assembly is determined. Layout is to the manufacturing department what preliminary design is to the engineering department. Standardization is initiated at this point and close association with production engineering is essential. Here too, the necessary steps must be taken to assure economical service when the final product reaches the field.

DETAILING: The detailers are responsible for supplying the drawings for the fabrication of each part. It is at this stage that the idea starts to be translated into tangible individual units and where the initial steps toward standardization are consummated. If not done at this point, considerable back-tracking and unnecesary repetition of work will be required before the product attains a proper degree of integration into the rest of the line.

The detailer can make manufacturing difficult or easy. Through his close association with the layout man he can and must achieve close association with production engineering. If not, he can create many minor nuisances in the fabrication of the product through his specifications of trim, finish, fillets or any of the other details which may work and function satisfactorily whether difficult to manufacture or simple. The detailer must identify each part by a system of part numbering. This follows the general practice of the department and is particularly important in production and material control.

Is Check on Specifications

BILLS OF MATERIAL: When the detailer has finished his work, bills of material must be prepared. Too frequently this function becomes a detailed listing job, when by its very nature, it should be a check on the specification of materials done by the men preceding him. The individual preparing bills of materials should not have authority to change specifications but he should have the ability to recognize that the materials specified could be changed to advantage in order to secure raw material standardization, to substitute more economical materials, or to utilize excessive stocks of material which may be available.

ESTIMATING: The estimator summarizes the work preceding him in order to develop a tentative material and labor cost. In doing so, he must maintain close liaison with purchasing, standards and production control. If mistakes are made at this point, costly errors may result through initiating a project which should not be initiated, or through rejecting a project which might be desirable.

PROJECT APPROVAL: All of the foregoing steps have been accomplished by one or more individuals under the direction of the chief engineer. Many of the steps may be done by one man or separate men may be used depending upon the size and capabilities of the particular group under consideration. Continual check and control has been maintained by the chief engineer and the project has now been brought to a point where executive approval must be secured before proceeding. The review of the project is usually accomplished by a committee made up of the key executives. It is good practice to include in this group the chief executive, the manufacturing head, the financial man, and the sales executive.

If the project has been clearly outlined and the work of the engineering department has been well conceived and followed out, approval of the next step is practically automatic, unless there has been a change in general business or market conditions. This step is the development of an experimental model.

Making Experimental Model

PILOT MODEL: Production of the pilot model is a step which transfers the project into a tangible product. There are two stages to this step—the production of the parts and their assembly. It is good practice to put the parts through the shop on an experimental order in order to take full advantage of the manufacturing experience of those who ultimately will have to produce the product. Careful and detailed records should be maintained of every step in the operation in producing each part, and this data serves as an excellent check on the estimator. There must be close liaison between the design engineer, production engineering and the key manufacturing personnel. Numerous ideas will be developed as parts go through the shop and meticulous attention should be given to properly recording each one of them. Throughout the preceding steps, it is assumed that attention is given to utilization of existing equipment, but at this stage every consideration should be given to refinements which will assure maximum utilization of existing equipment.

It is important that consideration be given to inspection requirements throughout the design stages but when the experimental parts are going through the shop it is doubly important that close liaison be maintained with the inspection department and that the finalization of inspection standards be determined at this time.

Experimental assembly of the pilot model is usually accomplished in an isolated area either in a section of the general assembly department or a separate space provided for this purpose. In the experimental assembly the bugs are worked out of the model and the important thing to be remembered is to make accurate records of all of the development work done both in assembly and in subsequent improvement operations.

Numerous changes are usually required before engineering is ready to secure final approval for production. Needless to say, the importance of inclusion of every change before releasing drawings and

(*Concluded on Page* 184)

Analyzing Circular-Arc Cams

Simple construction based on the familiar Scotch yoke permits rapid determination of velocity and acceleration

By Philip K. Slaymaker
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DISK cams with profiles made up of circular arcs offer a popular method of obtaining controlled motion. The sides or flanks of the cam are arcs drawn tangent to the base circle and to the rounded nose, *Fig.* 1. Layout of such cams is easy and convenient, but it is not generally realized that there exists an extremely simple method of analyzing the follower motion when a flat-faced follower is used. The purpose of the present article is to explain this construction, which affords the designer a quick method of determining velocities and accelerations needed in designing the complete cam and follower mechanism.

Action of a circular-arc cam may be compared with that of a pin and slotted sliding-bar (Scotch yoke) mechanism, *Fig.* 2, the pin of which is simply a circular-arc cam having one 360-degree arc. In *Fig.* 2 let V_p represent the tangential velocity of the crank pin P. This is the vector sum of the components V_s along the slot and V_b representing the velocity of the bar B. $V_b = V_p \sin \theta$ in which θ represents the angle of rotation of the crank AP. Such motion is known as simple harmonic.

If the velocity of the pin P is represented to scale by the radius AP, the velocity of the bar will then be $AP \sin \theta$. If this value is laid off as an ordinate at the position of the bar for the angle θ it will locate a point on the circumference of the crank circle, which also is the velocity curve of the sliding bar.

Acceleration, being the change in velocity for a unit of time, dV/dt, may be written $d(AP \sin \theta)/dt$ which becomes $AP \cos \theta$. In this case AP represents to scale the normal acceleration of P with respect to the center A. If $AP \cos \theta$ is plotted against bar posi-

Fig. 1—Profile of circular arc cam. Flank radius is tangent to base circle and nose radius

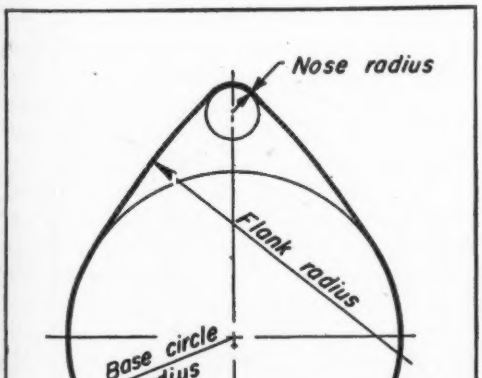
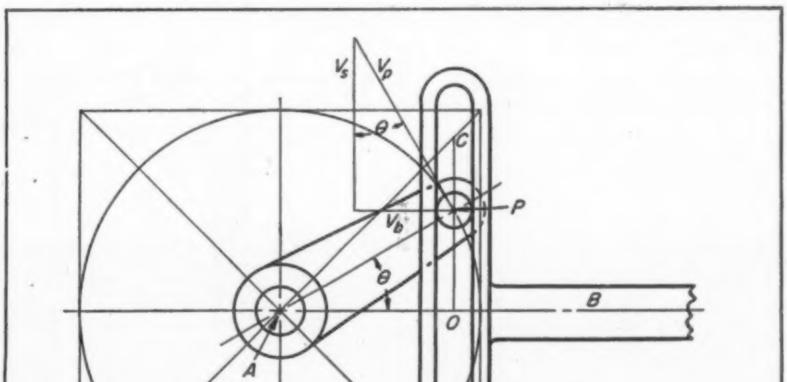
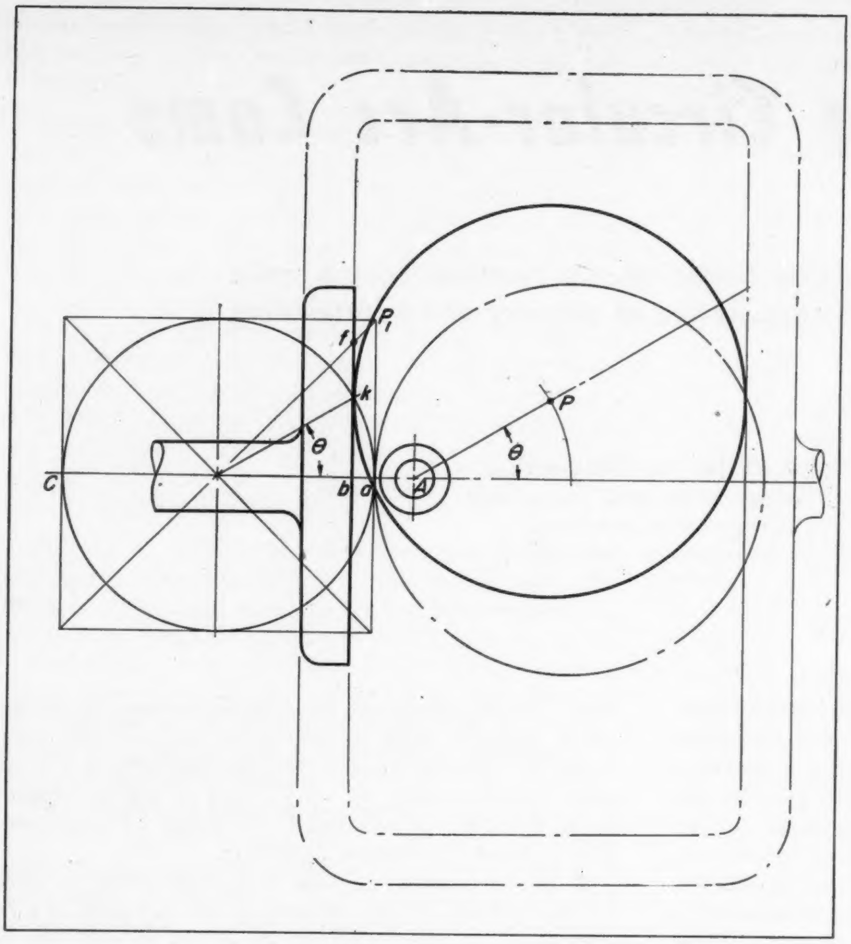


Fig. 2—Scotch yoke mechanism which is the basis for the analysis of the circular arm cam motion



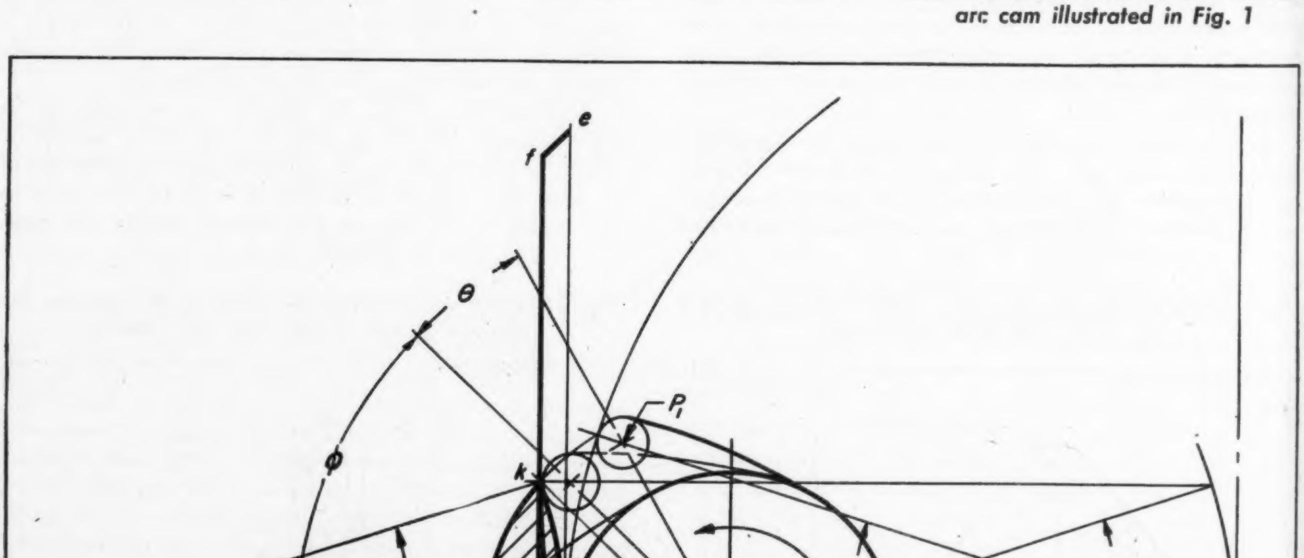


tion for various angles of rotation, the result will be a line drawn at 45 degrees through the center of travel of the bar, that is, through the center of the circle which represents the velocity curve. At the beginning of the stroke the acceleration will be represented by an ordinate equal in length to the radius *AP*. At midstroke where the velocity is maximum the acceleration line will cross the line of centers showing the acceleration to be zero. From this position on, the acceleration will be plotted below the center line as a negative value and at the end of the stroke will again be equal in length to *AP*.

In *Fig.* 2 the velocity of the bar for the position shown is the ordinate *OP* and the acceleration is the ordinate *OC*. If the diameter of the crank pin is made larger there

Fig. 3—Left—Scotch yoke mechanism with pin diameter increased to show the similarity with the circular arc cam

Fig. 4—Below—Construction of velocity and acceleration curves for circular arc cam illustrated in Fig. 1



will be no change in the character of the motion but the width of the slot will, of course, be made larger to accommodate the larger pin. Let the pin now be expanded until it includes the center *A*, *Fig.* 3. The mechanism now becomes an eccentric circle with eccentricity equal to *AP*. Also, the widened slot or frame may be modified so that the contact is on one side only and the result is an eccentric circle used as a cam and driving a flat-footed follower. The distance traveled by the follower will be twice the radius *AP*, equal to the diameter of the circle *ac*. The velocity curve will be the circle drawn on the diameter *ac*, and the acceleration will be indicated by lines drawn at an angle of 45 degrees through the center of this circle.

Keeping this construction in mind, consider the radial flank cam shown in *Fig.* 4. The cam is shown in the position at the beginning of the stroke of the follower. Note that the acting faces of the cam are made up of two curves which form, respectively, the flank and the rounded nose. The flank is drawn so as to be tangent to the base circle of the cam and also to the arc forming the nose.

Flank Is Portion of Eccentric Cam

At the beginning of the stroke of the follower the point of contact is that of the tangency of the radial flank with the base circle. The completed circle with this flank radius will be an eccentric cam with diameter *D* and center at *P*. Now draw a line from the center *P* through the point P_1, which is the center of the rounded nose of the cam. The angle that this line makes with the line of centers is marked θ. When the eccentric cam has revolved through this angle θ the line $P\,P_1$ will become parallel to the line of centers and the contact with the follower will be at the tangent point of the radial flank with the rounded nose of the cam. The motion of the radial flank has moved the follower from *a* to *b*. The velocity curve will be the arc with radius equal to *AP* and drawn from *a* to *k*. The ordinate *bk* represents the velocity of the follower at the position *b*, and is equal to $AP \sin \theta$. The ordinate *ae*, made equal in length to the radius *AP*, represents the acceleration of the follower at the beginning of the stroke. As motion continues, acceleration is represented by a line drawn at 45 degrees, from *e* to *f*. The acceleration of the follower at the position *b* is represented by the ordinate *bf* which is equal to $AP \cos \theta$.

Rounded Nose Effects Deceleration

At this position, *b*, the motion of the follower is now picked up by the rounded nose of the cam. The motion then continues from *b* to *c* with rapid deceleration.

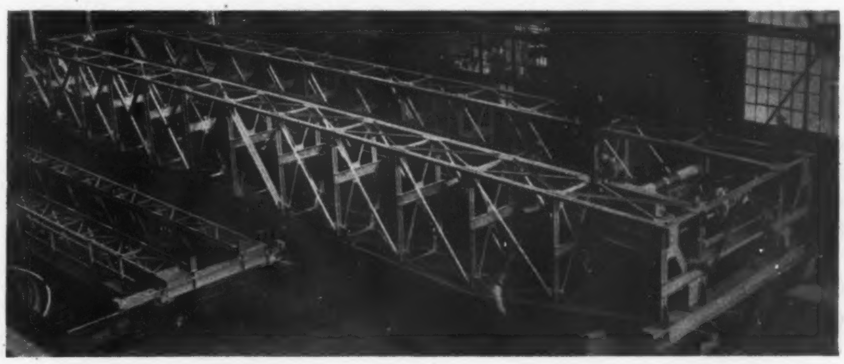
Velocity curve will be an arc with radius equal to AP_1 drawn from *k* down to *c* at the end of the stroke while the cam revolves through the angle ϕ. The acceleration at the position *b* will pass through zero since the follower has reached its maximum velocity, and will be shown below the center line as a negative acceleratiton and made equal to $AP_1 \cos \phi$. The acceleration line will be continued at an angle of 45 degrees from *g* to *h* where the ordinate *ch* will be equal to the radius AP_1.

If the angular velocity of the cam is represented by ω, then *ae*, the acceleration at the beginning of the stroke, will be $\omega^2 AP$; and *bf*, which represents the acceleration at the position of maximum velocity, will be equal to $\omega^2 AP \cos \theta$. Also, the negative acceleration *bg* will be equal to $\omega^2 AP_1 \cos \phi$ and *ch* will be equal to $\omega^2 AP_1$. The maximum velocity represented by *bk* is equal to $\omega AP \sin \theta$ and also equal to $\omega AP_1 \sin \phi$.

Aluminum Effects Weight Saving in Crane Structure

ALUMINUM alloys used in the crane structure illustrated in the accompanying photograph have approximately the same strength as structural steel. However, because of the lower elastic modulus, the depth of the girders had to be increased in order to prevent excessive deflections. Notwithstanding, the total weight is only 51,735 lb compared with 94,000 lb for a standard crane fabricated from steel.

As a result of the weight saving it was possible to employ a motor having 30 per cent less horsepower and to effect a reduction in the weight of the supporting steel structure. Maintenance is expected to be simpler and less expensive because the crane bridge will never require painting. Extruded channels and angles and rolled plates make up the structure of the 97-foot girder. Designed and built by Dominion Bridge Co. for the rod mill of the Aluminum Co. of Canada, the new 15-ton crane was subject of extensive research and experimentation prior to actual design.



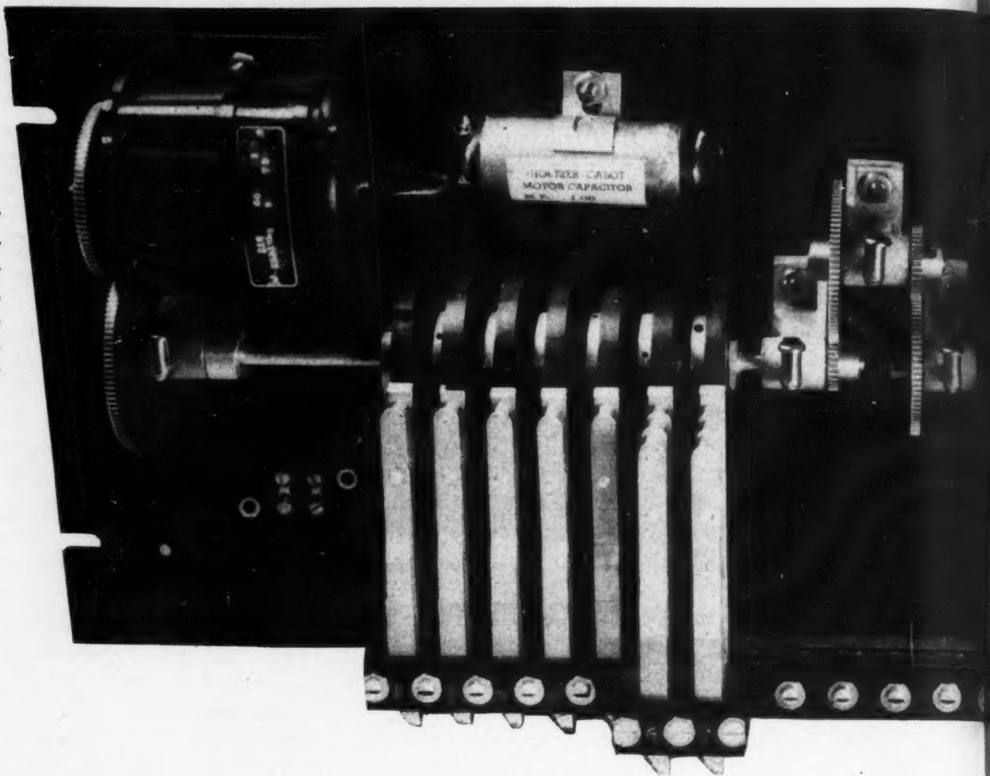


Fig. 1—Basic sections of timer are illustrated by this nonresetting unit. Actuating devices, cams in this instance, control multiple electrical contacts. Driving mechanism consists of gearing only; power source is electric motor

Time Control Mecha

. . . *their design and application*

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DESIGN problems associated with time-control mechanisms and other small machines have much in common. The outstanding difference, perhaps, is the high precision required of devices in the time-control field. This requirement has led in many instances to the development of unique devices and systems which should be applicable to a wide variety of machines. This article will, therefore, discuss the various mechanical arrangements which have proved themselves particularly valuable and reliable.

The basic industrial-timing device may be considered to include a driving motor, a driving mechanism, actuating devices, and the air-valves or electrical contacts being time-controlled. *Fig.* 1 illustrates a typical cam type time control unit.

Driving motors for such controls are usually fractional horsepower or fleapower size and of the synchronous or other constant-speed type. Usually they include built-in worm or spur-gear reductions to drop the motor speed from the neighborhood of 3600 rpm down to the practical range which starts approximately at 60 rpm and runs to a matter of one revolution in several weeks. The mechanical design of a time control starts with suitable mounting of this motor, flange or foot type as may be required, preferred or available. The final output shaft from the driving motor then couples into the driving mechanism.

Within the confines of the driving mechanism section of the time control, further gearing may be employed in order to operate the actuating devices (rotating arms, cams, etc.) at the required timing speed. Even when no further speed change is necessary, gears may be used to transmit the motor torque through an intervening distance or to reverse the direction of rotation. Spur gears are chiefly cut brass or bronze from 64 to 24 pitch, $14\frac{1}{2}$-degree pressure angle and either solid-bodied or spoked. They usually are run

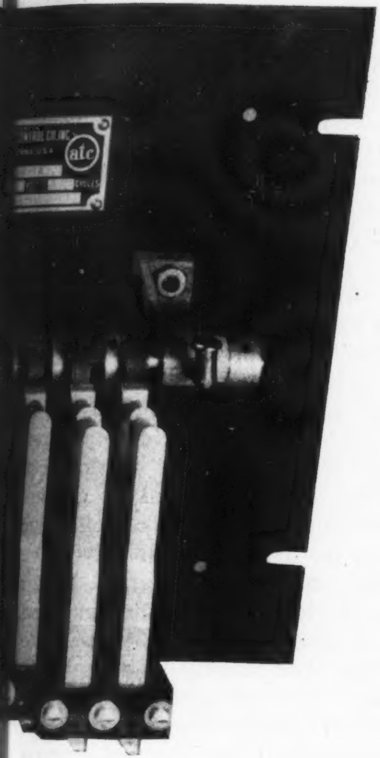


Fig. 2 — Right — Sector gearing, showing change gear at lower right. By replacing this gear with gears of other sizes the time-control speed can be changed quickly

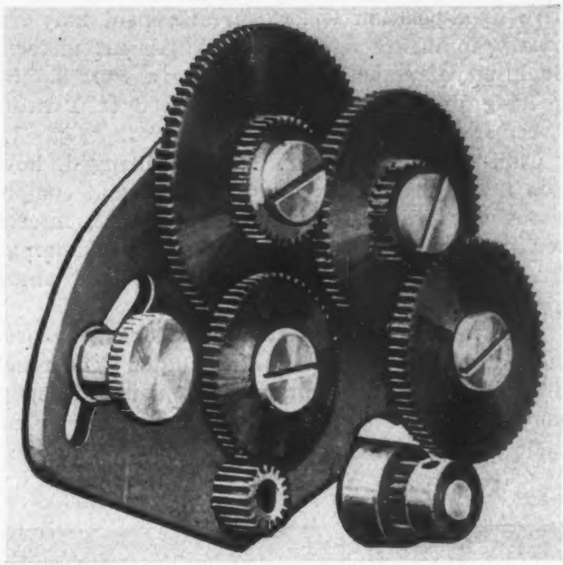


Fig. 3 — Below — Positive locking arrangement is provided for both of the sector gears shown at right front of this dual driving-motor timer

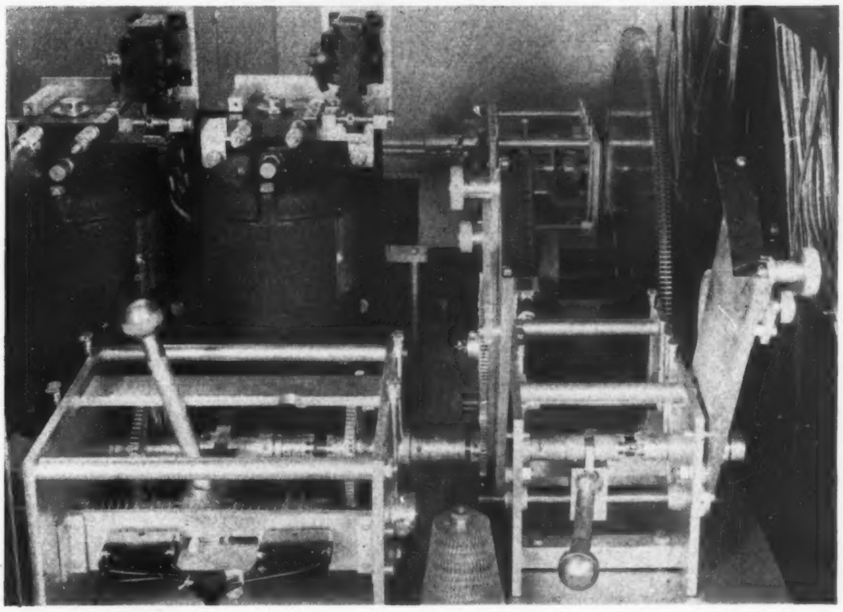
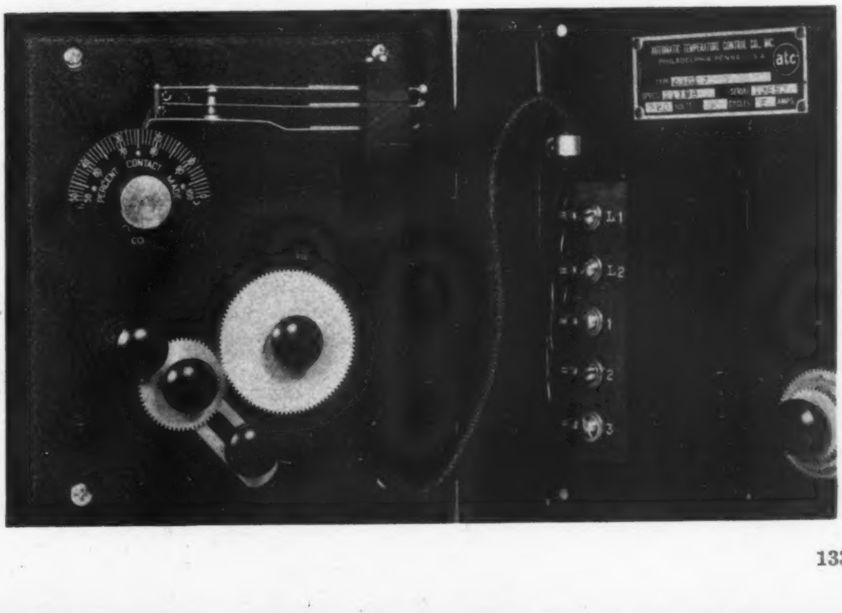


Fig. 4—Below—Variation of the sector-gearing principle allows driving gear, sector gear and driven gear to be changed by removing thumbscrews



free of lubricants. In a few cases, steel gears are used for strength, punched gears for low cost, and gears of a synthetic material for electrical insulating and noise eliminating qualities.

Sector gearing, as illustrated in *Fig.* 2, is widely employed in order to facilitate quick-change gearing and thereby to provide a variety of output speeds to the actuating devices. The sectors, upon which are mounted the intermediate idlers and compounds, are commonly held in mesh with the final or changeable gear by a friction thumbscrew. In larger units, however, where a higher order of torque is being transmitted, a posi-

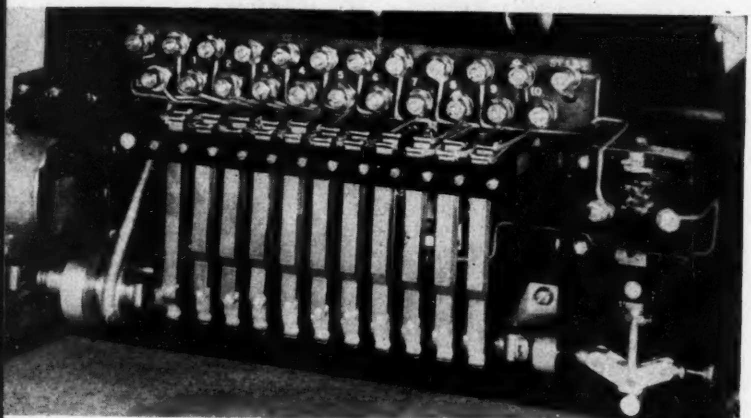
tive fixed-position locking arrangement may be necessary to insure against disengagement under load. Such an arrangement is shown in *Fig.* 3. Sector gearing provides approximately a 6 to 1 ratio between slowest and fastest output speed.

Cam shaft speed may also be changed, however less flexibly, by changing the idlers and compounds about in a variety of center holes. An interesting combination of this fixed-center gear changing and the sector type gearing is shown in *Fig.* 4, where the gears and idler are interchangeable.

Lost motion is frequently a serious gear problem in reversing type time control units. The resulting timing error may be minimized by using as few gears as possible in the driving mechanism and by use of such arrangements as the split-gear, with one half spring-loaded against the other to eliminate any back lash in the mesh with the adjoining gear.

Gearing alone, as described, may constitute the driving mechanism, especially in the case of nonresetting time controls. Such time controls drive continuously in one direction, sometimes repeating the program over and over, and other times finishing one program and then waiting for a deliberate external starting impulse before going through the next. However, the other major division of time control action, namely resetting, calls for a clutch and return springs or the equivalent. Resetting timers go through one program and are then returned quickly in the reverse direction to the starting position. This is most commonly accomplished by a solenoid - operated clutch, controlling the transmission of motion between the driving motor and the actuating device. Thus, when the solenoid is energized, the clutch faces are forced together and the driving motor drives the actuating device through the desired program. When it is de-energized, the driving motor is disconnected and a return spring or gravity member causes the actuating device to snap back quickly to a positive-stopped "start" position. A variation of this arrangement provides a spring-loaded normally-engaged clutch which is disengaged for resetting only when the solenoid is actuated.

Both smooth and serrated-faced clutches are commonly used in time controls. Smooth-faced clutches require more force to engage firmly but usually take less motion to accomplish this engagement. However, the fact that they provide an infinite number



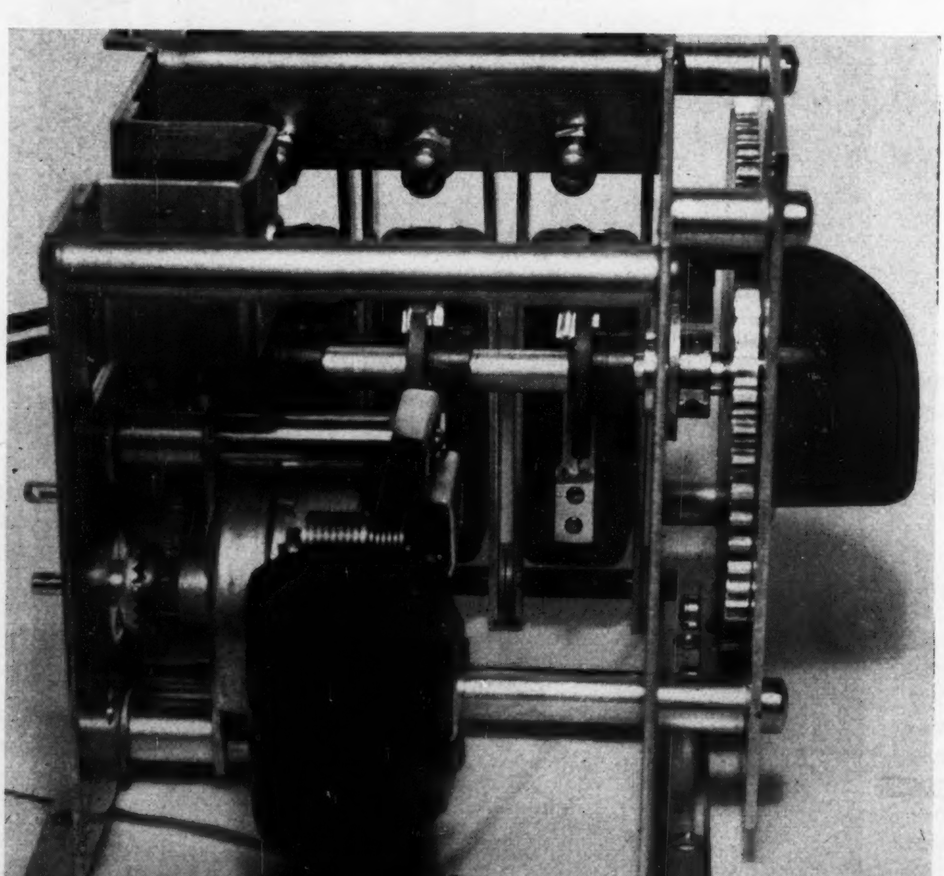


Fig. 5—Left—Above — Metal-to-metal smoot-faced clutch (left end of cam shaft) is used on this program timer. Clutch is actuated through hollow cam shaft by solenoid at right end of timer

Fig. 6 — Left — Serrated-face clutch direct-connected to motor is engaged by solenoid. Clutch is located at left front of timer

of engagement positions is an important feature for maintaining a constant "starting" point and accurate minimum time settings. Serrated-face clutches require more motion to engage, since the full tooth or serration depth must be transversed but they require less force to actuate. Since the teeth provide a more positive mechanical connection than the friction of smooth-faced surfaces, the limited number of positions (as fixed by the number of teeth or serrations occurring in the number of degrees of rotation employed) that the driving and driven faces can take with respect to each other is objectionable, as explained, since it limits the timer's accuracy and minimum adjustments. This objectionable limitation can be minimized by designing the clutch into a relatively high speed point in the driving mechanism. In this manner, the number of teeth or serrations for total angular travel is increased, decreasing the angular error on contact.

For the smooth-faced clutches, nonchipping and nonsticking metals or platings, and friction materials such as cork, rubber, and synthetic products are used in pairs or in combination. *Fig.* 5 shows a resetting cam timer equipped with a metal smooth-faced clutch, while *Fig.* 6 shows the use of a 45-degree saw-tooth faced clutch on a resetting type of dial timer. Frequently, a slip clutch, *Fig.* 7, is used to permit hand setting of the timer without the necessity of disengaging the driving motor from the actuating devices.

Timer driving shafts range from 3/16 to 1/2-inch in diameter depending upon the shaft lengths and the number and size of the actuating devices used. Cold-rolled steel, drill rod, and especially prepared shafting materials are used as may be dictated by strength-of-material calculations, based upon a dead minimum of axial and torsional deflection. All deflections will produce some timing error, and more than a normal number of bearings may have to be employed in order to minimize these effects. When it is necessary to electrically insulate the shaft of a time control, a laminated plastic may be used.

Bronze and prepared metallic sleeve bearings are usually adequate for time controls operating in the normal speed range for industrial applications. Rarely does a time control operate in the optimum ball-bearing speed range. However, ball bearings are used to eliminate thrust friction at shaft ends and to accommodate slight shaft bending and misalignments in long lengths of shaft when, for standardization purposes, it is not practical to use larger shafts.

With time controls operating almost constantly, lubrication of bearings must provide for long, maintenance-free periods of operation. Light machine oils are fed to bearing surfaces through over-sized reservoirs and capillary wicks and unusual precautions are taken to insure the absence of any abnormal friction which might create a timing error.

Too little friction, on the other hand, may cause coasting or other form of overtravel and time error in a timing device. This situation is frequently remedied by the use of frictional braking deliberately applied in the correct amount and constantly pres-

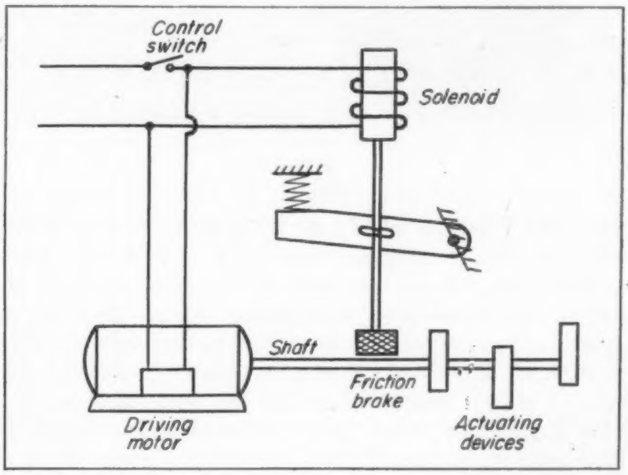
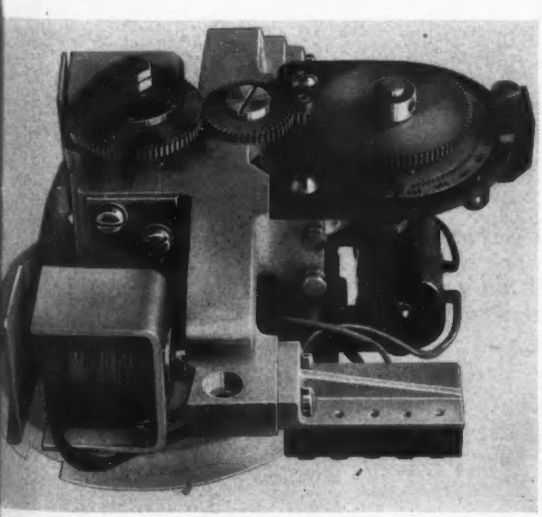


Fig. 8—Right—Above—Electromagnetically operated friction brake. Solenoid keeps friction brake disengaged while motor is operating

Fig. 7—Below—Slip clutch, seen on gear at upper left, is used to facilitate hand setting without necessity of disengaging gearing



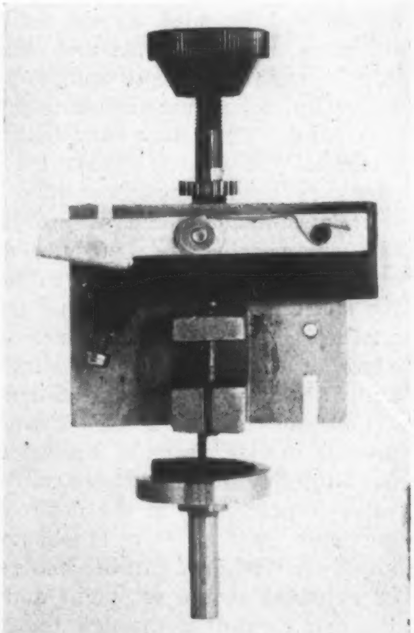


Fig. 9—Right — Side-cut constant-rise cam is used to actuate snap switch. The switch is positioned with respect to the cam by knob-turned worm

ent, or an electro-magnetically actuated brake which provides anticoast error only after the desired timing program has been completed. The constant-friction brake can be used only when the driving motor has power in excess of that needed to drive the cam shaft at the correct speed and without danger of stalling. If the overtravel of the shaft is not due to power in excess of that needed for correct timing, but rather to the inertia of the actuating devices, then an electric or air brake must be used and arranged so as to be applied only after the driving motor is shut off and the timing program completed. *Fig.* 8 is a schematic sketch of this arrangement.

The coasting problem is not present in the reset type of unit, since the actuating devices are brought

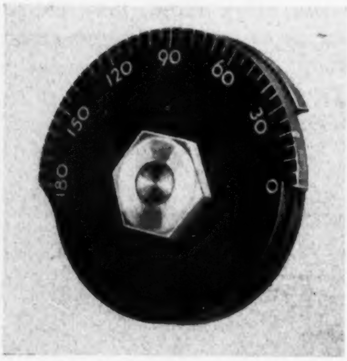


Fig. 10 — Split type cam allows 180 degrees of adjustability of the low level of the cam

back by a return spring or by gravity to a positive stop after the program has been completed. This positive stop must be firm and accurately fixed in order not to produce any timing error. If it lacks sufficient rigidity each resetting action will provide a hammer blow and eventually cause the stop to slip out of place, thereby changing the cycle-time length. Air dampening vanes, dash pots and spring cushions are used to eliminate this shock in cases where a riveted or welded stop cannot be used because of the necessity of adjusting this stop position.

Probably the most widely used actuating devices are cams, rotating arms and tripper plates. Cams may be metal or plastic and range in diameter from 1 inch up to the more accurately adjustable 5 and 6-inch cams. They may vary from 1/16 to ½-inch in thickness. A variety of shapes and cutting arrangements is used, depending upon the air valves or electric contacts which are to be operated against the cam peripheries. Locknuts, setscrews and other clamping schemes are used to fix cams securely on the shaft in the required time relationship one with another. Graduations are included on the sides or edges of the cams and sometimes on etched plates and disks for the purpose of making adjustments.

Constant-rise cams, *Fig.* 9, are frequently used to provide a wide range of timing adjustment out of a fixed total cycle. The electrical contact or air poppet valve is positioned at the desired distance along the maximum radius. Here it will not be actuated while any lesser radii are turning under it but will be closed or actuated at the set point and for the balance of the cam's rotation through the greater radii. Such mechanisms, while simple and dependable, are not usually as accurate as some of the other mechanisms described. The gradual rise occasioned by such a cam fails to provide the snap action considered desirable for the actuation of electrical contacts or air valves. This drawback is overcome if the contacts or valves themselves include spring-loaded toggles or other quick-action devices.

The cam material will vary with the diameter and thickness of the cam, the speed at which it will operate, and the process preferred for forming. Punched cams of plated steel or brass and aluminum provide considerable strength but require additional hand-dressing to give a smooth edge. Further, they are not electrically insulating and thus are not satisfactory if the particular type of electrical contact to be operated will ride on the cam. Cut metal cams are expensive to form for all normal applications. Plastic cams can be formed by punching if the resulting rough edges can be hand-smoothed or ignored. Machine-formed plastic cams are more satisfactory from a standpoint of accuracy, and at the same time they provide electrical insulation.

Split Cams Provide Easy Adjustment

Split cams, illustrated in *Fig.* 10, are used to provide adjustment of the ratio of the low and high portions of a two-level cam. The halves of such a cam are clamped together against a cork, fiber, or Vellumoid disk. Various setscrew and locknut arrangements are used to provide adjustability between the halves and between the whole cam and its shaft.

In a rotating-arm unit, the electrical contacts or air valves to be actuated may be fixed in position, with the motor driving an arm about the central shaft from an adjustable starting point, or the electrical contacts may be adjustable with respect to a fixed starting point. Upon the shaft indication dial is set the time equivalent of the distance from this starting position to the point of actuation of the electrical contact. Variations of this action are numerous and include repetitive action around the dial (turning a circuit on and off for desired portions of the total time cycle), and control of the time dura-

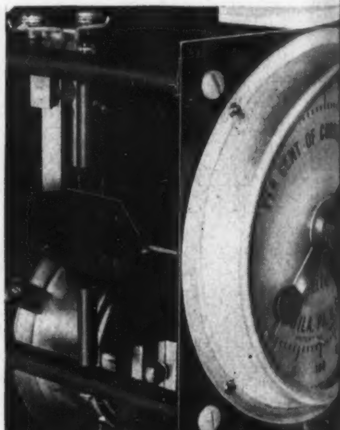


Fig. 11 — Rotating arm in back of setting dial is used to trip switch off and on

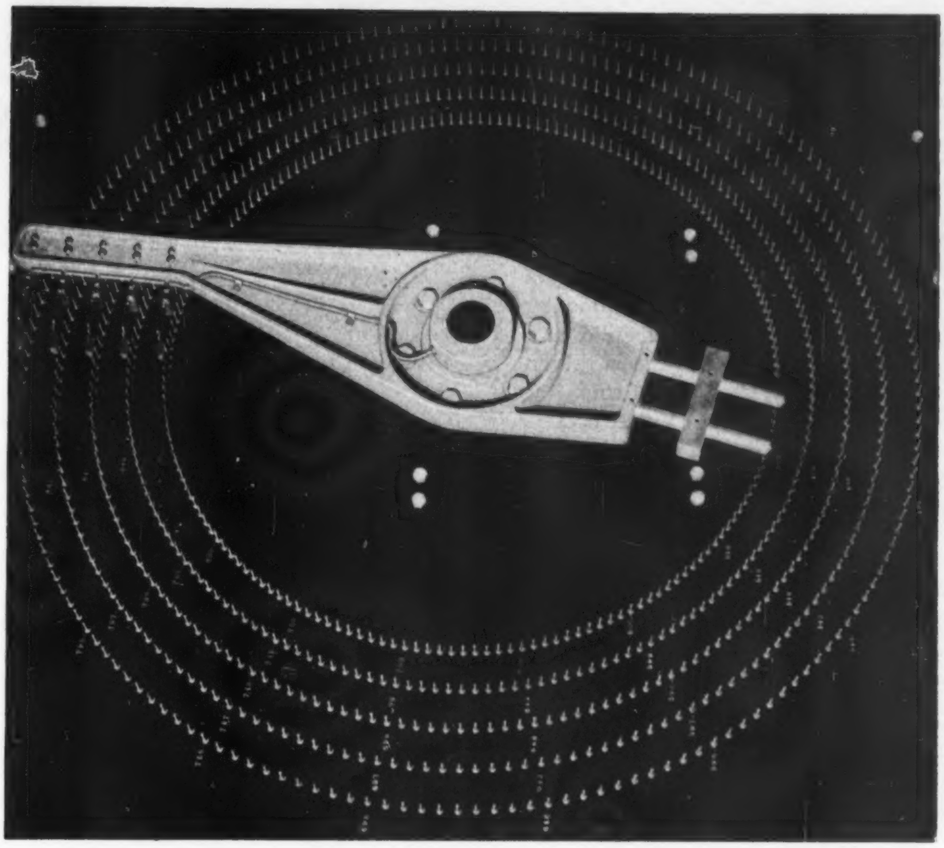
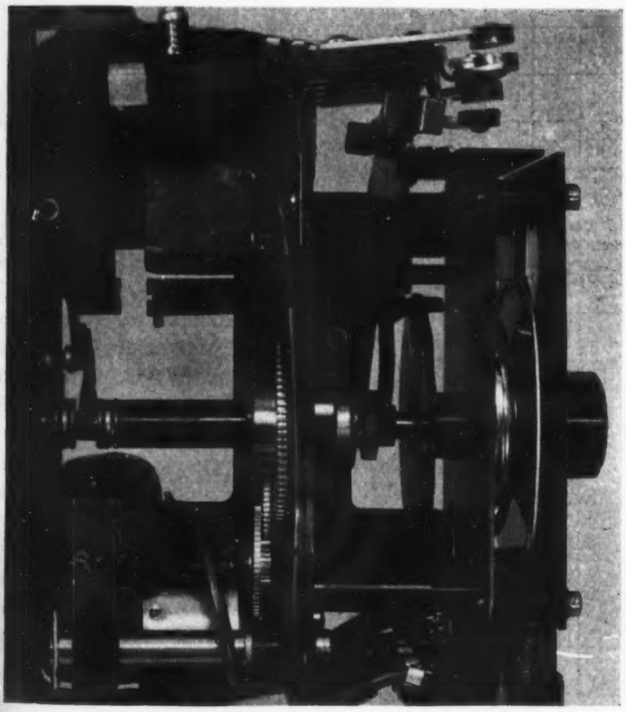


Fig. 12—Right—Rotating arm carries timing impulses through five contacts to fire concentric rings of stationary pin type contacts

Fig. 13—Below—Tripper plate, upper right, actuates electrical contacts. Plate is tilted by action of driving mechanism at end of time delay



tions for two, but rarely more, rotating arms. *Fig.* 11 shows an interesting arrangement of a repetitive-action dial timer. As the rotating arm mechanism passes through zero on the dial, the electrical contact is tripped "on." When the mechanism passes the dial pointer setting, it is tripped "off" and stays off until it again passes through zero. A particularly impressive use of the rotating arm principle is shown in *Fig.* 12 where a five-point rotating arm controls the impulses of 900 electrical circuits. The cast-aluminum arm is flange mounted to the time-control shaft and counterbalanced for minimum timing error by an adjustable weight.

A tripper plate arrangement is shown in *Fig.* 13. Here, the rotary motion provided by the driving motor through the gearing, clutch, or other driving mechanism is translated into linear motion to tilt the tripper plate. Spring-loaded onto the top of this plate are the various contacts to be actuated at the end of the time set on the timer dial. When the tripper plate makes its linear motion at the end of the program these arms fall down, their notches receiving the tripper-plate edge. The contacts are frequently pulled down against the tripper plate at the beginning of the cycle by the same solenoid that may be used for actuating the clutch of a reset type of unit. Tripper plates may also be driven in straight-line action by a rack-and-pinion arrangement and, as it proceeds through its travel, they trip the various electrical contacts or air pilot valves which may be adjusted at various time intervals.

Time controls must be designed with an appreciation and knowledge of the expected frequency of operation and the time of one complete timer cycle. Whereas a continuously operating timer having a two-second cycle will require special attention to be given to wear, a timer which goes through a 15-minute cycle once a week will inflict negligible wear on its mechanical components, and may be designed for this lighter duty if no problem of parts standardization is involved.

Why Pnu

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EFFECTIVENESS of the pneumatic system which was discussed in Part I of this article, can best be understood by comparison with a hydraulic and an electrical system for a given design requirement—in this instance Consolidated Vultee's XB-46, a 93,000 pound four-jet bomber with tricycle landing gear. To reduce drag at takeoff and while over the target, AAF specifications for this airplane required that the landing gear fully retract in five seconds and that the bomb-bay doors operate in a second or less.

Pertinent comparative data for these three systems have been reduced to a number of illustrative charts and curves. In TABLE I is shown the weight breakdown figures for a proposed wing bomb-bay system installation, and in TABLE II pertinent figures of weight breakdown are shown for a multiple-unit system (XB-46) consisting of landing gear, fuselage bomb-bay and brake system installations. A comparison of unit weights of electrical vs. hydraulic vs. pneumatic actuating units is shown in *Fig.* 15, while electrical vs. hydraulic vs. pneumatic operational power required of engine to achieve actuation of units involved during flight is shown in *Fig.* 16.

Previous reports and papers have been presented showing that weight saving can be obtained by use of hydraulics over electrical systems (24-v, d-c), particularly in the SAE report "Comparison of Hydraulic and Electrical Accessory Systems in Aircraft," by W. C. Trautman and R. E. Middleton. It should be pointed out that an electrical system using 400-cycle, 3-phase, 208/120 volts a-c does have weight advantages over the 24-volt d-c system, but this has not been developed for applications such as the XB-46 to date. However, the pneumatic system will still show

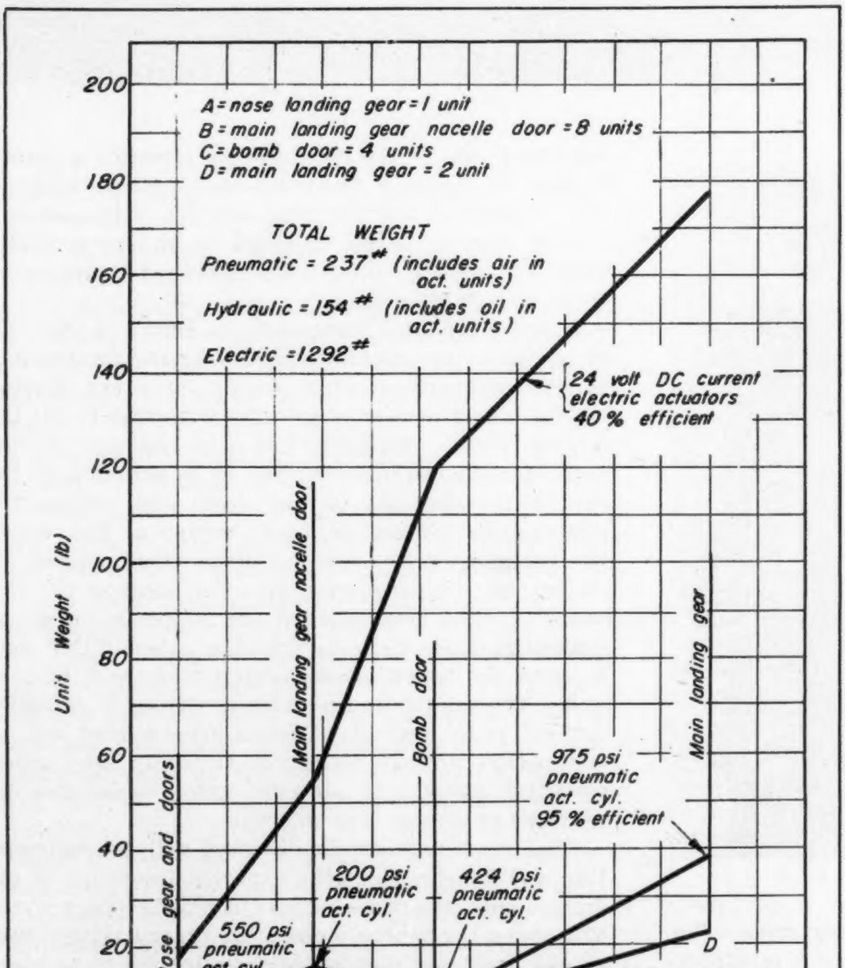

Fig. 15—Electrical vs. hydraulic vs. pneumatic actuating units weight comparison based on the XB-46 airplane

Pneumatics

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Part II—Development and Research

considerable weight saving over the a-c system.

DEVELOPMENT AND RESEARCH: During the early months of 1945 letters were sent to all domestic manufacturers of pneumatic equipment, requesting drawings and samples of their products. The net result of these efforts was the following equipment designed for gun charging:

1. A 28-volt, direct-current, electrically-driven compressor with an output capacity of one-half cubic foot per minute free air at 1250 psi discharge pressure. (This rating was based on sea-level inlet pressure of 14.7 psi and temperature of 59 F)
2. Selector valves, both manual and electric-solenoid operated, for pressures up to 750 psi
3. Pressure regulators designed to regulate pressure from 50 to 1000 psi with a storage pressure of 1250 psi
4. Relief valves designed for 0 to 500 psi and 500 to 1000 psi relief pressures
5. Accumulators of 52, 150 and 300 cubic-inch capacity, designed for 1250 psi storage pressure
6. Brake valves for emergency differential braking and parking.

Assured by manufacturers of this equipment that it could be satisfactorily and safely employed to charge and store a pneumatic system pressure of 1500 psi and operate at pressures up to 100 psi, it was purchased. As the bomb bay door was the simplest to test, we constructed a mock-up and began research. The performance of this pneumatic system was favorable enough to warrant further research, so design of a landing gear test stand which duplicated in function the main landing gear and its actuating mechanism was begun

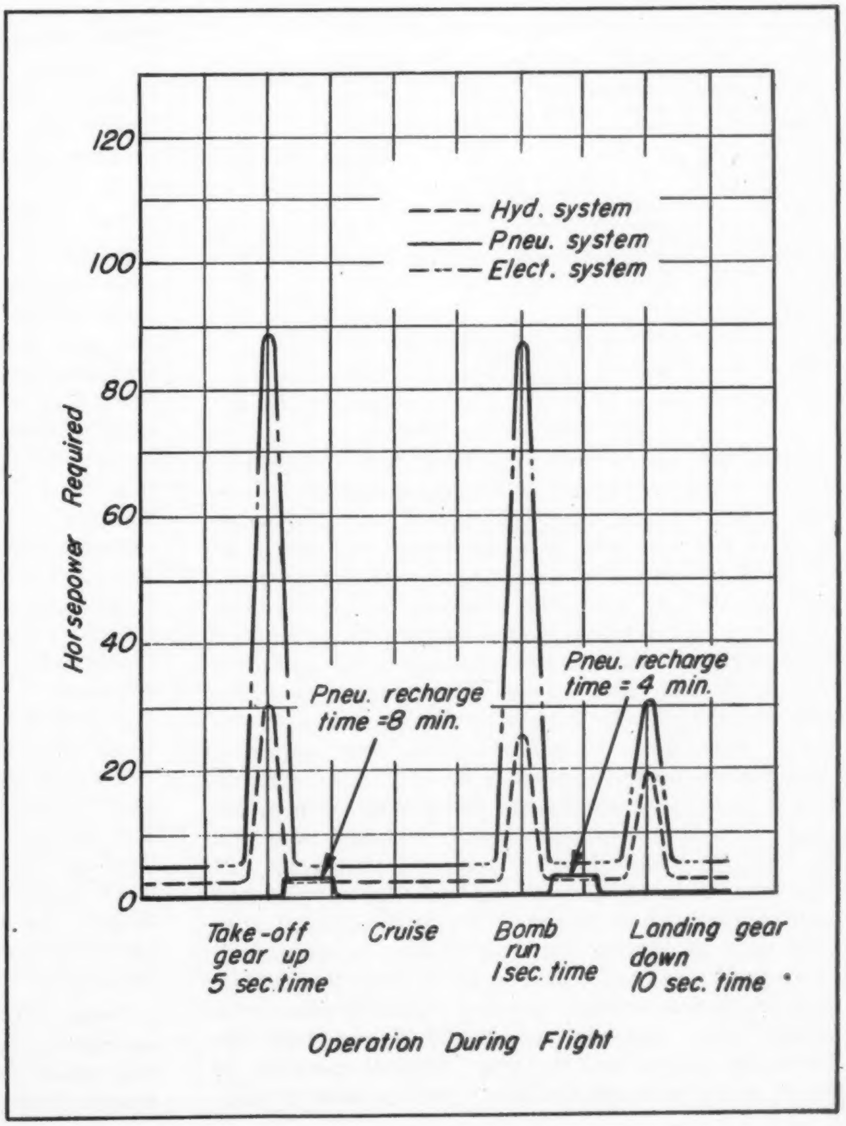


Fig. 16—Electrical vs. hydraulic vs. pneumatic operational power required of engine to achieve actuation of units involved in the XB-46 system

to enable adequate exploration of the possibilities.

Faced with the requirement of retracting the complete landing gear in five seconds, it was decided to retract the gear itself in four seconds and the doors in one second. This meant that with each gear weighing 2034 pounds, 12.28 horsepower would be required. To store the potential energy for accomplishing this work a tubular structure was employed in building the landing gear and the supports of the power plant and landing gear. These double-purpose accumulators provided 2634 cubic inches of volume at 1500 psi storage pressure for each gear, or 329,000 foot-pounds of potential energy.

Completion of this test stand provided further proof that pneumatics was a good choice, but it also revealed that a great deal of research was in store.

Selector valves, solenoid controlled: After repeated cycling, the valves tended to ice up and stick. Too, after setting for even a short time without operation, the valves tended to stick and periodically during operation the valves evidenced excessive leakage. An analysis of the situation and discussion with an engineer who had experience with this type of valve revealed that a rubber seat is not satisfactory for 1000 psi operating pressure and, by sticking under repeated loading, causes refrigeration. Rubber seals expand when in a static condition and force out any lubrication which may lie between themselves and the wall of the bore in which they slide. The rubber then tends to adhere to the wall, requiring considerable force to break it loose. By experiment it was found that adding five per cent paraffin to the standard rubber compound practically eliminated this tendency to stick. Further research, particularly at low temperatures proved the paraffin-impregnated seal to be the best and it is the writers' belief that this type of sealing material should be developed.

A third problem which evolved was the rubber seal which was encased by a sleeve held in place with a wire clip. The clip periodically slipped down between the poppet and the seat. Overall operation of these valves was unsatisfactory and, seeking another type of design, the "shear-flow" valves, previously mentioned, proved to be the answer to this problem.

TABLE I

Weight Breakdown of a Proposed Wing Bomb-Bay System Installation

Part	Per Plane (No. req'd)	Hydraulic (lb)	Pneumatic (lb)
Pneumatic accum. @ 17.36-lb each (including air)	4		69.44
Hydraulic reservoir @ 38.00-lb each (including oil)	1	38.00	
Pneumatic compressor & access. @ 17.44-lb	2		34.88
Hydraulic Pump @ 15.00-lb each	2	30.00	
Air in tubing with press. trapped			0.21
Hydraulic fluid in tubing		21.74	
Tubing		29.52	8.30
Clips, fittings & flexible hose		34.77	21.69
Pneumatic selector valve @ 2.00-lb each	4		8.00
Hydraulic selector valve @ 6.00-lb each	2	12.00	
Press. reducing valve @ 1.40-lb each	4		5.60
Press. shut-off valve @ 0.50-lb each	2		1.00
Press. by-pass valve @ 0.50-lb each	2		1.00
Manual shut-off valve @ 0.80-lb each	5		4.00
Relief valve @ 0.40-lb each	4		1.60
Press. warning switch @ 0.50-lb each	2		1.00
Shuttle valves @ 0.35-lb each	10		3.50
Hydraulic relief valve @ 3.00-lb each	2	6.00	
Hydraulic shuttle valves @ 0.50-lb each	10	5.00	
Pneumatic act. cylinder @ 7.30-lb each	4		29.20
Hydraulic act. cylinder @ 6.32-lb each	4	25.28	
Total Weight		202.31	189.42

Pressure regulators: The original units delivered such a small valume that in order to obtain a four-second operation it was necessary to install five units in parallel. A purchase order was issued to the vendor, specifying the requirements in detail and authorizing construction of a suitable regulator but, because of the urgency of delivery and the lack of empirical data with which to design the unit, the second regulator built was no better than the first. Turning to another manufacturer who was taking an interest in development of pneumatic equipment for aircraft, a third unit was built and since the airplane was practically completed by this time the new regulators were tested on it. The high-pressure regulators failed to allow the required flow at the time the gear was almost retracted. Being at a loss to do otherwise, raising the gear without regulating the supply pressure was tried. Because the solenoid valve shut off the supply pressure at the instant the gear was in the uplock, there was no waste of pressure or energy. This procedure worked very well.

Low-pressure regulators were also installed in the airplane and were apparently satisfactory for the first few flights. Trouble soon appeared, however, and on one of the ensuing flights the regulator completely malfunctioned, causing a structural failure of the landing gear doors (the emergency pneumatic system lowered the gear for a safe landing). Following this mishap the vendor redesigned the unit. To date it has performed very satisfactorily.

Hydraulic Snubbers Necessary

Snubbing cylinders: Initial efforts to cushion the main landing gear during extension consisted of precharging the actuating cylinder on the exhaust side. The gear was effectively cushioned, but the resulting adiabatic pressure returned it into the uplatch. To offset this a relief valve was installed and achieved smooth operation. However, specifications required a manually operated lowering mechanism for use in case of a complete loss of normal and emergency pneumatic pressure, so it was necessary to install hydraulic snubbers. The design of the snubbers embodied an orifice and a metering pin which was varied in size and shape to suit the speed. During a trial run the pressure regulator on the down side failed to function properly and delivered four times the design pressure. This threw excessive loads on the snubber orifice, which failed, and the gear came hurtling down. Close inspection revealed no structural failure.

Tests of the snubber revealed that it is not necessary to vary the speed of the gear through the travel. The internal part of the snubber was redesigned by deleting the orifice and metering pin and installing a self-cleaning fixed orifice with a check valve for refilling. An accumulator provided for expansion and contraction of the oil. The snubber has performed excellently through several thousand operations.

Brake Valves: An existing differential-control emergency brake valve was purchased and an order was issued for the development of a similar normal system brake valve to meet our requirements. When

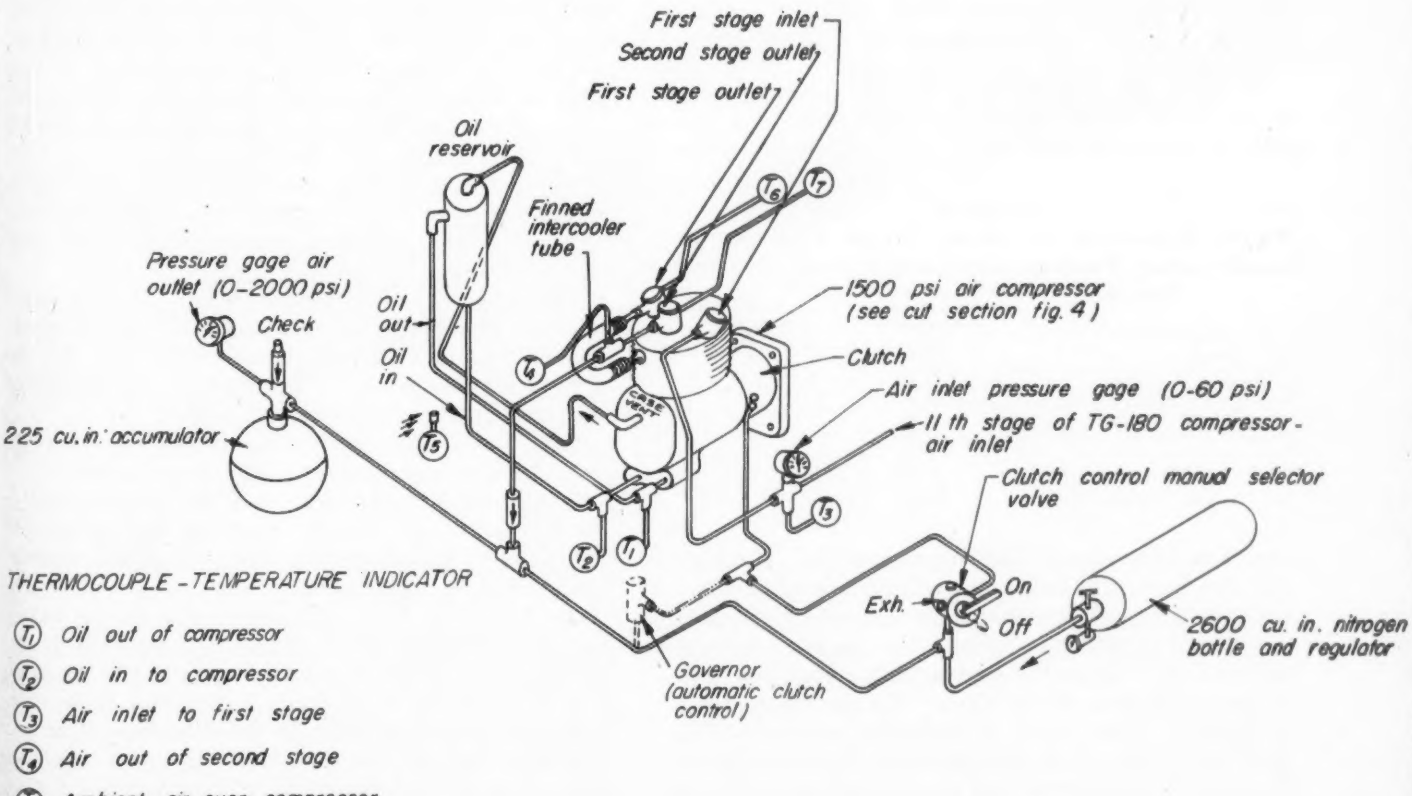
received, the emergency and parking brake valve showed that its leakage was so excessive as to make it of little or no use. The manufacturer was not interested in doing anything further, so the only choice was to install a shut-off valve and pressure regulator in the airplane for the emergency and parking brake. This arrangement has been very successful.

When the normal system brake valve was completed its performance was not much better than the emergency brake valve and certainly not within the specifications. We redesigned it and replaced the dumbbell-shaped poppet, which leaked badly, with the optical flat plate-and-seat poppet principle and met with gratifying success. After determining the correct foot-pedal force by actual braking tests on the airplane, our test pilot stated that these were the smoothest-functioning brakes he had ever operated on either large or small planes. The brakes can be applied or released instantly at all required temperatures.

Compressors: Because the brake manufacturer substituted a multiple-disk brake which was 100 lbs heavier than the specified spot brake, it was necessary to increase the landing gear operating force. This left three choices: Replace the landing gear actuating cylinders with ones of larger bore, add back-up accumulators, or increase the storage pressure in order to get two full cycles of landing gear operation without recharging. Inasmuch as the changing of the compressors seemed the simplest, the manufacturer was contacted and agreed to increase the capacity from 0.50 cubic feet to 0.90 cubic feet per minute and the pressure from 1500 psi to 2000 psi. After being rebuilt the units were tested, but they overheated under load, used excessive oil, and put out only one-half of the guaranteed volume. Shortly thereafter during taxi tests the electric motors on the compressors caught fire. This presented a serious problem because there were no other compressors on the market. One solution remained with flight date only a few days off. We removed the compressors, reduced the storage pressure to 1500 psi and installed five 2600 cubic-inch bottles in the bomb bay as back-up storage, *Fig.* 2. This arrangement, which provided for four complete cycles of the landing gear, was used for the first six flights.

With the apparently successful development of a five-cubic-foot-per-minute at 1000 psi engine-driven compressor, large main landing gear actuating cylinders were ordered. These were installed after the sixth flight and gained an additional cycle with the existing volume. These compressors, *Fig.* 4, were

Fig. 17—Below—Test setup for Westinghouse compressor on *TG-180 engine for XB-46 pneumatic system*



tested on an engine in the test cell at Muroc Army Field, *Fig.* 17, and after demonstrating satisfactory characteristics they were installed on No. 1 and No. 3 engines of the airplane for flight. The pressure governor failed to function satisfactorily, however, and a manual control valve had to be installed in the cockpit to enable the pilot to turn the compressor on and off at will. These compressors are still functioning satisfactorily.

Accumulators: One of the 52-cubic-inch accumulators developed a leak. After taking it down, installing new seals, and subjecting it to proof pressure, we found that the bottle bulged at both ends until it looked like a dumbbell (an earlier proof-pressure test had revealed no evidence of deformation). Consequently, a 150-cubic-inch and a 300-cubic-inch accumulator bottle were removed from the airplane and put to test. When these also failed, we immediately started designing our own accumulators. These accumulators were proofed at burst pressures without deformation to make certain that no failure would occur in the airplane. To date they have been very successful although rather heavy.

Closely related to accumulators is the question of moisture accumulation. Although this was considered to be one of the detriments to pneumatics, we drained our entire system of 22,000 cubic inches after approximately three months of operation and obtained only a cup of water and oil emulsion. We have specified on each accumulator nameplate that the unit be drained after each flight. Even in rainy weather, however, the amount of vapor ejected is of minor consequence.

In conclusion, it would be well to enumerate a few of the items which, from these first steps into the field of high-pressure pneumatics, urgently require

TABLE II

Weight Breakdown of XB-46 Multiple-Unit System Landing Gear, Fuselage, Bomb-Bay & Brake Systems

(Based on operating temps. of —65 F to 160 F)

Unit	1500 Psi Storage Pneumatic (lb)	3000 Psi Operating Hydraulic (lb)
Power Supply	79.72	134.00
Main Landing Gear Normal System	305.40	278.53
Nose Landing Gear Normal System	29.00	27.54
Nose L.G. & Main L.G. Emerg. System	54.00	67.54
Normal Brake System	21.00	60.00
Emergency Brake System	21.00	60.00
Normal Bomb Door System	93.00	162.50
Emergency Bomb Door System	25.00	135.30
Total Weight	628.12	925.41

considerable research and improvement. Although initially externally lubricated, a rubber seal expands and forces the lubrication from between itself and the cylinder wall. The rubber then tends to bond to the wall, and depending on the piston size, has been known to require up to 400 or 500 pounds of force to break it loose, even in hydraulic systems. The cure for this is either a permanently impregnated lubrication in the rubber seal or a metal seal which is sintered and has lubrication induced through the pores. This is entirely feasible, espeically in systems used intermittently and not required to maintain continuous high pressure.

Pressure regulators must be designed and built with a low-rate spring so that temperature changes and a very small adjustment do not cause high pressure changes. Every regulator received to date has had a high-rate spring. Under normal conditions this would be ideal for weight saving but the high-rate spring being short and stiff is too sensitive, especially so where the regulator bodies are made of aluminum and the differential of expansion is high. Regulators must also be capable of flowing air equivalent to the line size used and must have free return flow. These features will help to prevent icing or refrigeration due to expansion.

Relief valves when constructed of metal diaphragms, must be capable of repeated cycles without fatigue of the metal and should be capable of flowing one hundred per cent of the air through the line or should at least be capable of keeping the supplied pressure within safe limits.

Integral Snubbing Requires Development

Both hydraulic and pneumatic methods of snubbing actuating cylinders at the end of their stroke should be further investigated. Of all the pneumatic methods tried, a by-pass valve in the bomb-door system was the only one that proved successful. This system was based on restricted flow to the opening side of the cylinder and full flow to the closing side. When full operating pressure was reached, the by-pass valve closed off flow and opened the closing side of the cylinder to a restricted exhaust to atmosphere. This provided an adiabatic cushion on the closing side but ultimately allowed the air to bleed off and the full effective pressure to work to hold the door open. This gave us a very smooth bomb door operation in less than one second. Where large masses and forces are involved it is necessary that development be carried out on integral hydraulic snubbing.

Pneumatically operated starters must be developed, especially for jet engines which require ground service battery carts and make starting in remote locations impossible.

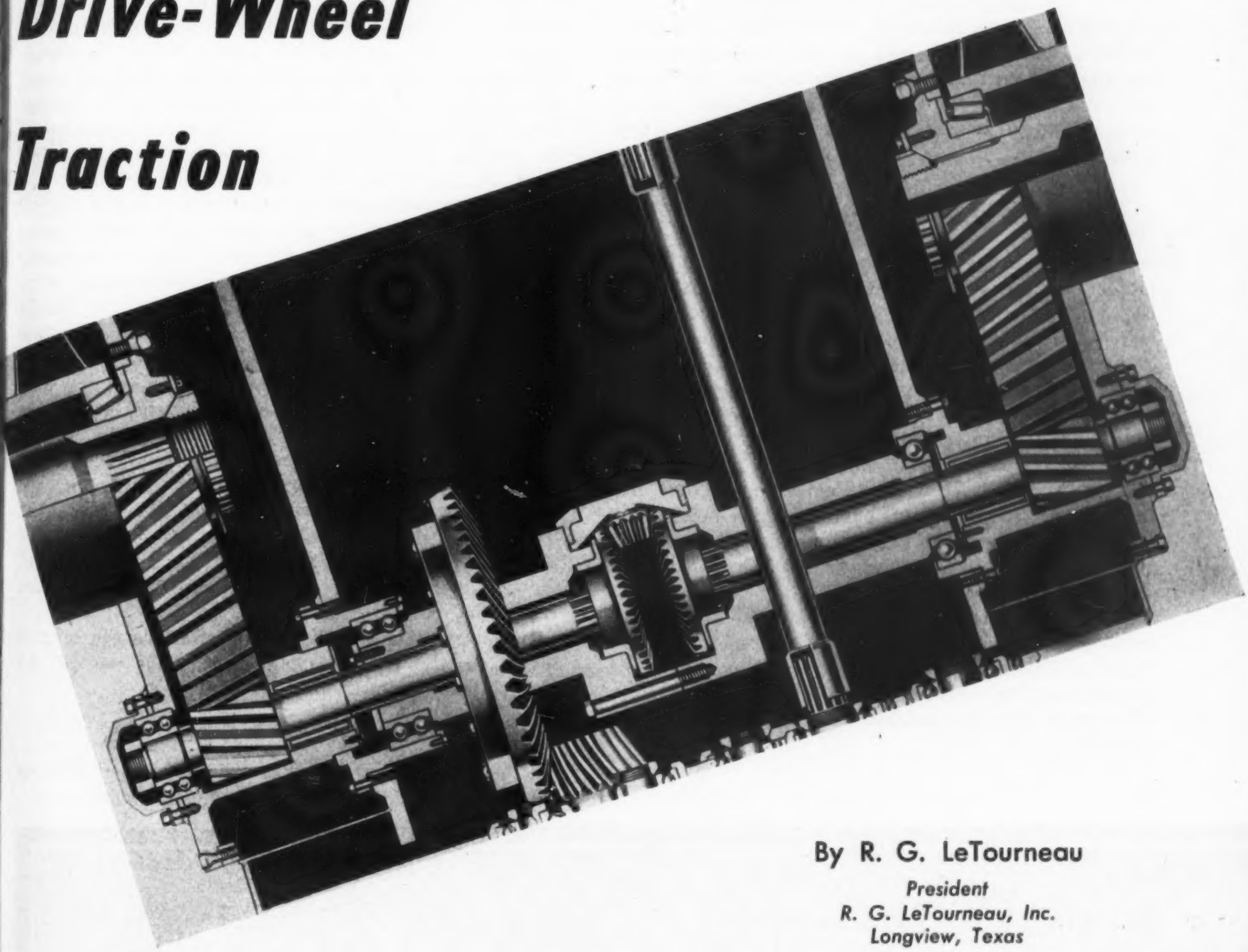
Pneumatically-driven motors with follow-up control must be developed for flap, surface control, steering and the like. Studies show that they can be built at approximately 25 per cent of the weight of an equivalent horsepower electric motor.

Pilot's seat and canopy emergency ejection by pneumatics should be thoroughly investigated.

Windshield cleaning, not only by pneumatically-driven wipers but also by spraying the windshield with fluid by an air-driven jet pump of the venturi type, should be investigated.

The foregoing facts point favorably to the adoption of pneumatics for all high-speed, heavy-load, intermittent operation of units on all aircraft. We wish to give credit to the following men and their companies for their assistance in the development of our pneumatic system: Mr. Lee Baldwin, Chief Engineer of the Weston Hydraulics Ltd. of Los Angeles, Calif.; Messrs. Barksdale and Flickinger of the Saval Co. of Los Angeles, Calif.; and Mr. R. Weber, west coast representative at Los Angeles for the Westinghouse Airbrake Co. of Wilmerding, Penna. All of the units shown in this article are patented or have patents pending by the above manufacturers.

New Differential Insures Greater Drive-Wheel Traction



By R. G. LeTourneau

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IN a conventional type of differential, as is well known, there are four pinions, set 90 degrees apart, running on bearings in a gear-driven cage. These four pinions operate between two bevel gears which are positioned on either side of the cage, and are splined to the right and left axles, respectively, of the vehicle. As long as the vehicle is traveling straight ahead on ground which affords equal traction to both drive wheels the pinions do not revolve on their axes, but carry the two bevel gears around with rotation of the cage just as if there was a solid shaft running through from the left wheel to the right wheel.

Fig. 1—Above—Large pinion bearings in Tournamatic differential create resistance to pinion rotation necessary to prevent drive-wheel slippage

When one wheel must go faster than the other as the outside wheel must in turning a corner, the four driving pinions revolve on their bearings to permit this action. Again, when one wheel hits a slippery place and loses its traction, exactly the same action takes place, and the slipping wheel spins while the wheel which has good ground underfoot remains stationary.

This slipping action, which is a definite disadvantage in the conventional differential in automobile operation on the highways, is an even more serious and frequent one in off-the-road operations, as in earthmoving and material handling. Many slippery

and rough spots, mudholes and other irregularities are encountered. A vehicle with a conventional differential attempting to operate under such adverse conditions is utterly helpless.

Obviously the way to give the wheel on good footing more pull than the one on slippery footing is to resist the revolving of the four driving pinions. In the conventional differential each driving pinion revolves on a small bearing having low friction. A very large bearing was needed to develop the required resistance, and was obtained in the Tournamatic differential by putting the bearing outside the pinion instead of inside. It is a lubricated bronze bearing and, as the drawings show, is considerably larger than the pinion.

Frictional Loading Analyzed

Assume that the coefficient of friction in the bronze pinion bearing is 0.16 (that is, roughly one-sixth of the load on the bearing is required to cause rotation), and that load on the pinion teeth is 2000 pounds on each side, making 4000 pounds bearing load. It will take 640 pounds (16 per cent of 4000) to overcome the friction. Then if the radius of the bearing is four times the radius of the pinion it will require four times 640 pounds or 2560 pounds more tooth load on one side than on the other to make the pinion turn. If, out of a total of 4000 pounds pinion tooth load, 2560 pounds more are put on one side than on the other, there will be 3280 pounds of tooth load on one side against 720 pounds on the other, or more than four times. In other words, both wheels will turn together until one gets this excess load, then they will begin to differentiate. The ratio is always the same regardless of the amount of the load, because the coefficient of frictional remains, for practical purposes, constant.

Actually, the pinion bearing has to be only about three times the diameter of the pinion to make one wheel pull four times as much as the other, because there is added friction from the thrust of the bevel pinion against its thrust bearing. The bevel gears also are housed in bronze thrust bearings of quite large diameter, and they assist in resisting the differentiating action of the drive pinion.

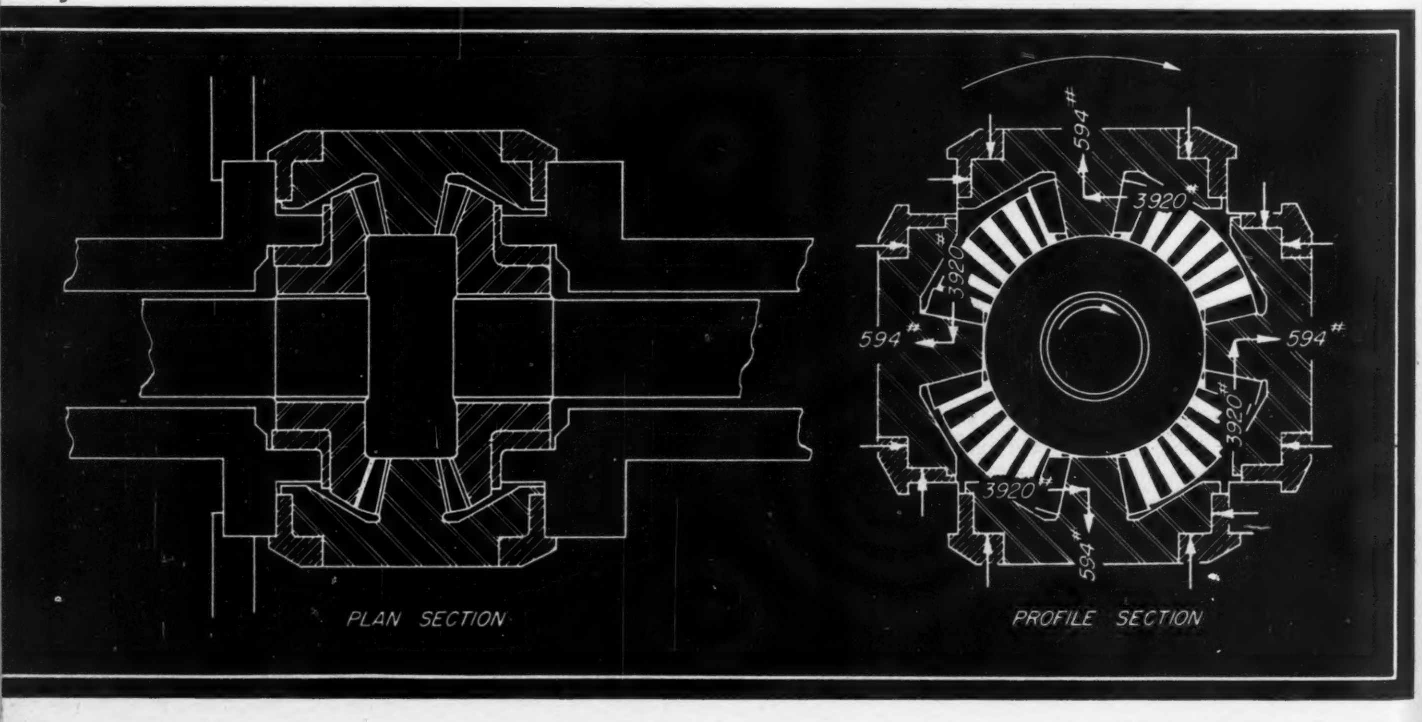
The accompanying cross sections, *Figs.* 1 and 2, show the radial bearing about three times the average pitch diameter of the pinion, while the thrust is taken partially at a diameter larger than the radial and partially at a diameter smaller than the radial. Thus the average diameter of the thrust load would be carried at a radius about the same as the radial load, or three times the diameter of the pinion.

It will be noted in *Fig.* 2 that with a radial load of 3920 pounds there is an added thrust load, resulting from the contact of the bevel gears, amounting to 594 pounds, or a total of 4514 pounds which, with a coefficient of friction of 0.16, will give 722.24 pounds. This multiplied by a three times radius gives 2166.72 pounds.

If another 400 pounds is added to the pinion load for the thrust load friction set up by the bevel gear, the total is 2566.72 pounds, which would be the amount of the load greater on one side of the pinion than on the other needed to cause it to revolve with a radial load of 3920 pounds. That gives a load of 3243.36 pounds on one side of the pinion and 676.64 pounds on the other side. This, it will be seen, imparts to one wheel considerably more than four times the pulling power of the other.

Because of the simplicity and effectiveness of this invention, the author considers it to be one of the best he has developed.

Fig. 2—Sections through Tournamatic differential showing magnitude and direction of load on pinions



MACHINE *Editorial* DESIGN

Let's not Repeat Error!

As in the case of the draft law in force during World War II, no specific criteria are set up in the act recently passed by Congress to defer potential scientists, engineers and other technologists from military service. It is generally recognized that one of the errors of the last war was the widespread induction of technical men whose service to the country in many cases would have been far greater had they been allowed to continue in their technical capacities or training. The same error may occur in carrying out the new selective service act unless regulations are established granting liberal powers of exemption to the various draft boards.

During the time the new law was under consideration, many statements were presented before the committees on armed services by representatives of technical and scientific groups. Appropriate emphasis was placed on the vital contributions to the war effort—including the development of the atomic bomb—made by men in these categories. It also was pointed out that research and development were seriously disrupted through the policies of the selective service system in the last war. Dr. Vannevar Bush, chairman of the Research and Development Board, claimed that we now are suffering through our failure to continue the training of scientists and technologists, there being a deficit in scientific manpower variously estimated to be between 40,000 and 150,000.

Responsibility for deferment under the new law is vested in the President, he being authorized to provide for the deferment from service of ". . . all categories of persons whose employment in industry, agriculture, or other occupations . . . or whose activity in study, research, medical, scientific or other endeavors . . . is found necessary to the maintenance of the national health, safety or interest." The suggestion has been made that the National Security Resources Board be charged with the function of advising the President regarding exemptions. It is to be hoped the NSRB, if this policy is adopted, will view the situation in its broadest aspects. Thus there would be increased assurance that the selective service act will be truly selective and that the manpower of the nation will be utilized in the most effective manner possible.

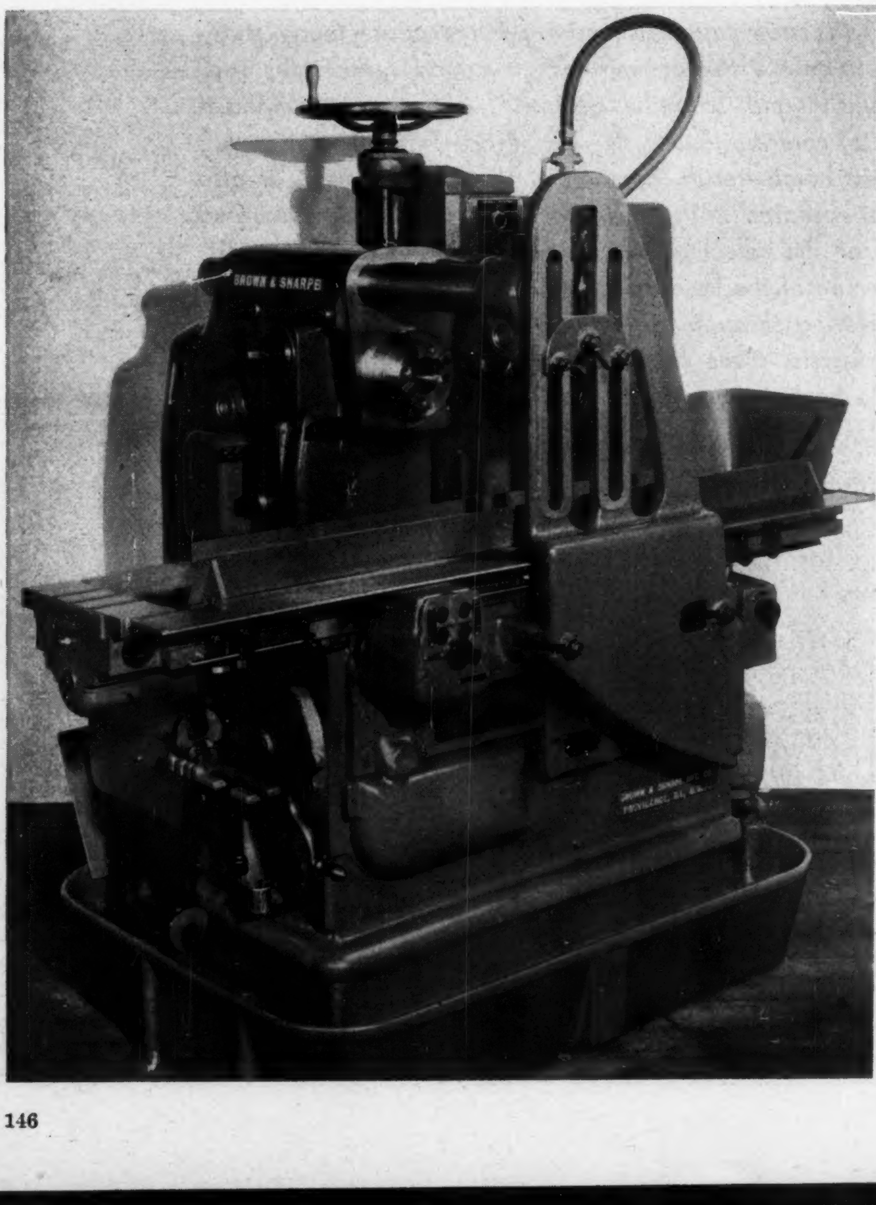
L. E. Jermy

DESIGNS OF THE MONTH

Improved Spindle Drive in Plain Miller

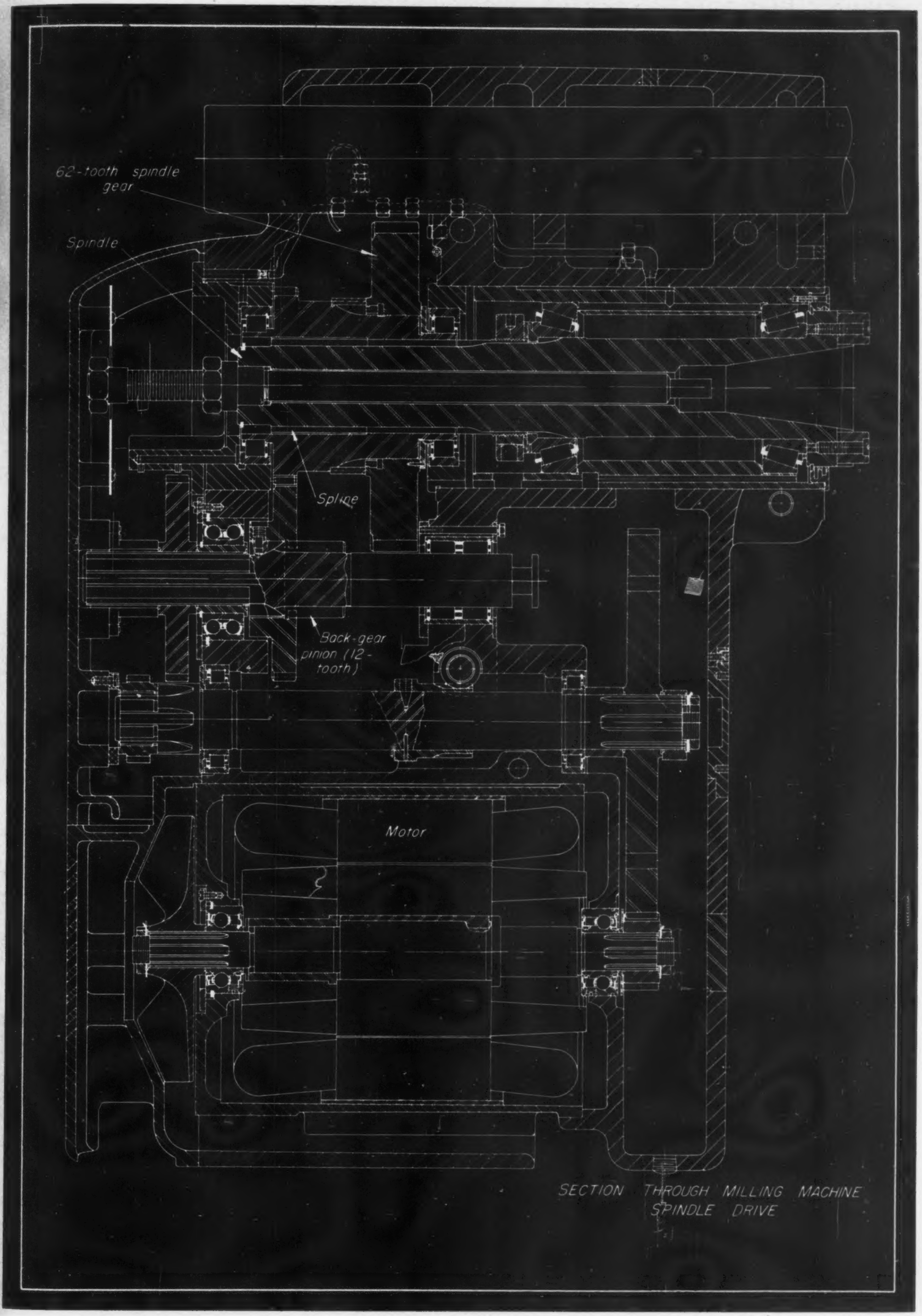
GEARING arrangement of the plain milling machine, below, is such that spindle windup is held to a minimum and ample power at requisite speeds is available for all types of cutters. As the cross section on the opposite page shows, spindle gears are not directly mounted on the spindle. Instead, the spindle is mounted in tapered-roller bearings toward the front of the machine, its rear end extending through the center of the spindle gear unit which is mounted in roller bearings. A spline couples the two units.

Low speeds available range from 25 to 635 rpm. High speeds range from 750 to 1800 rpm. The 12:62 back-gear ratio makes torsional windup of secondary shafts a negligible contributor to spindle windup. Secondary-shaft windup will be four per cent of the amount contributed with a one-to-one drive. The back-gear pinion is an integral part of the shaft, its 12 teeth being cut on a 13-tooth blank. This oversize blank aids rigidity and results in pinion teeth which have more complete involute action and a larger Lewis factor.

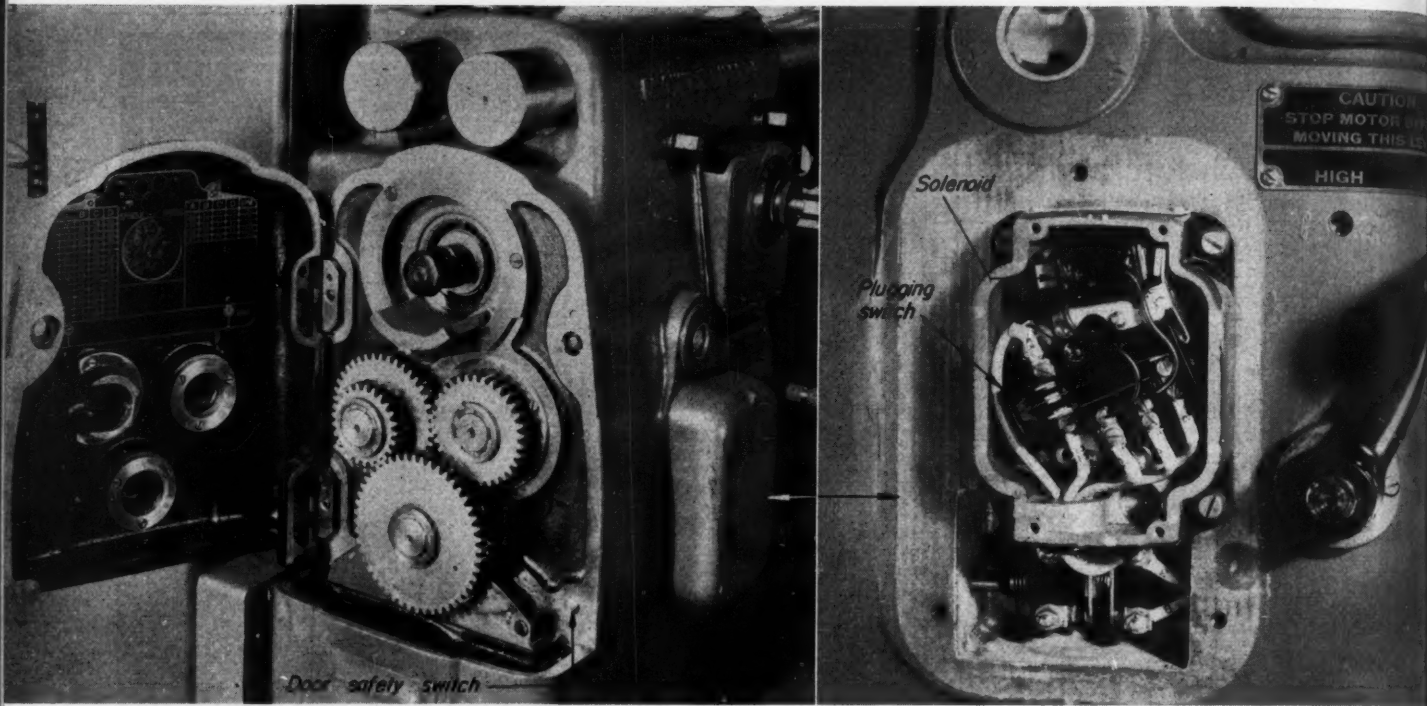


Most of the gears in the spindle drive are chrome-nickel-molybdenum steel, hardened and ground. Electrical controls conform to the Machine Tool Builders' Electrical Code. All controls, housed in a single, semi-dustproof compartment, are within convenient working height and there are no overhanging machine members. The code requires a disconnect switch. This is mounted in the control compartment. The handle which operates the switch incorporates a door latch so that the compartment cover cannot be opened and the controls exposed until the disconnect switch is moved to the off position.

Plugging brings the spindle motor to rest. Reversing control circuits are prepared for plugging or are opened to interrupt plugging by a permanent magnetic type of plugging switch. The plugging switch contact, which changes position



SECTION THROUGH MILLING MACHINE SPINDLE DRIVE

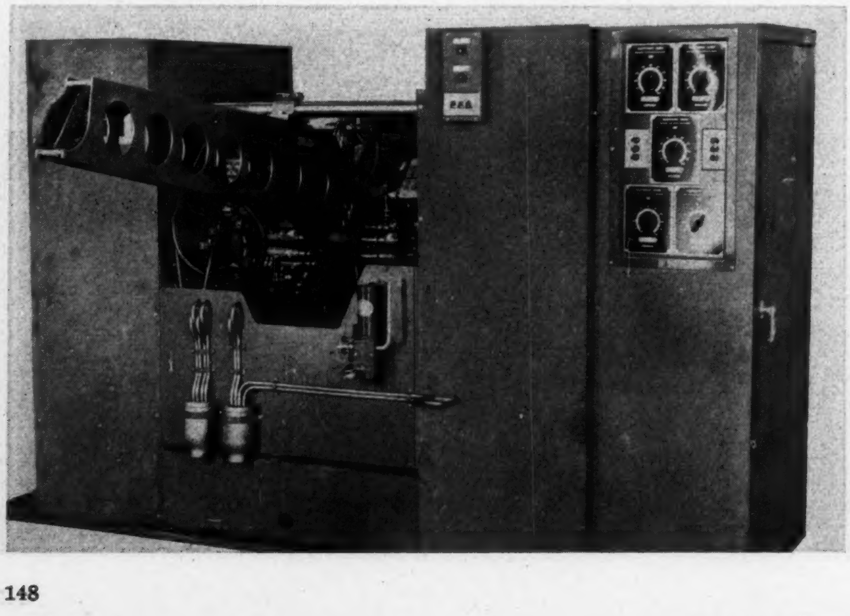


with direction of motor rotation, is shown in the photograph above. The solenoid seen at the top of the switch unit is energized whenever the spindle motor control circuits are completed. When control circuits are opened the solenoid releases the clapper and a detent latch holds the plugging switch contact arm in neutral position. This is a safety feature and no mechanical rotation of the spindle motor (hammering the wrench on the spindle arbor nut, for example) can jog the plugging switch and cause a control circuit to be unexpectedly closed.

The switch shown at the bottom of the plugging switch unit is operated by the rod at its left. The other end of the rod is actuated by the change-gear case door. Whenever the door is opened the spindle motor control circuit is opened and the machine made inoperative. Manufacturer: Brown & Sharpe Mfg. Co., Providence 1, R. I.

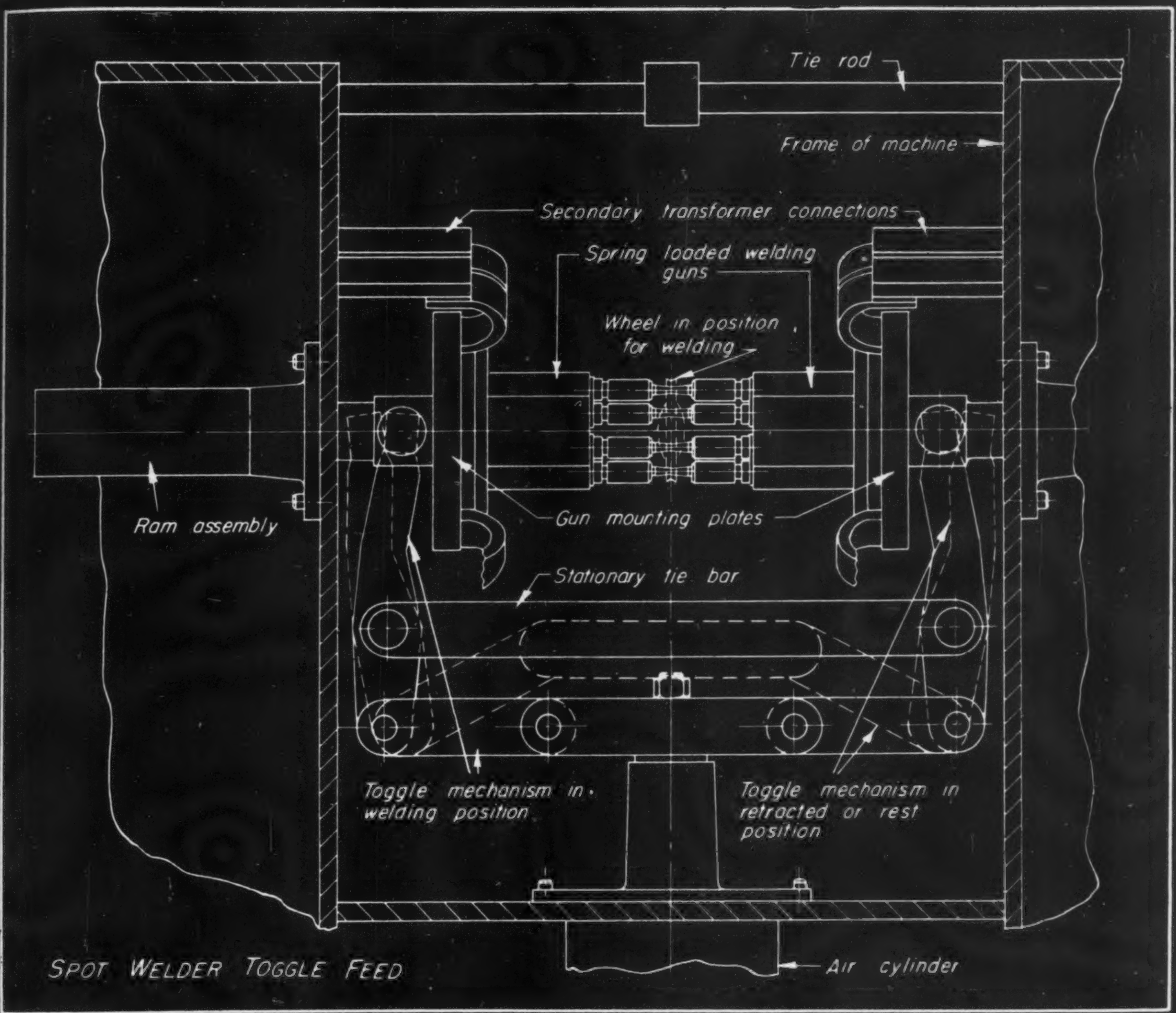
24,000 Spot Welds Per Hour

DESIGNED to automatically spot-weld scooter-wheel halves together, the multiple-head welder, below, combines electrical, hydraulic and pneumatic power and control. Its rate of production is 3000 wheels, or 24,000 welds per hour.



As the drawing at the top of the next page shows, the machine is essentially two welders mounted together, face to face, each with a set of eight electrodes. Each unit houses four 50 kva transformers, with the electrical control cabinet mounted at one end. A gravity feed magazine is provided which passes through the machine. When welding wheels of different sizes, a magazine for each size is employed and only slight adjustment is made in the position of the electrode cylinders.

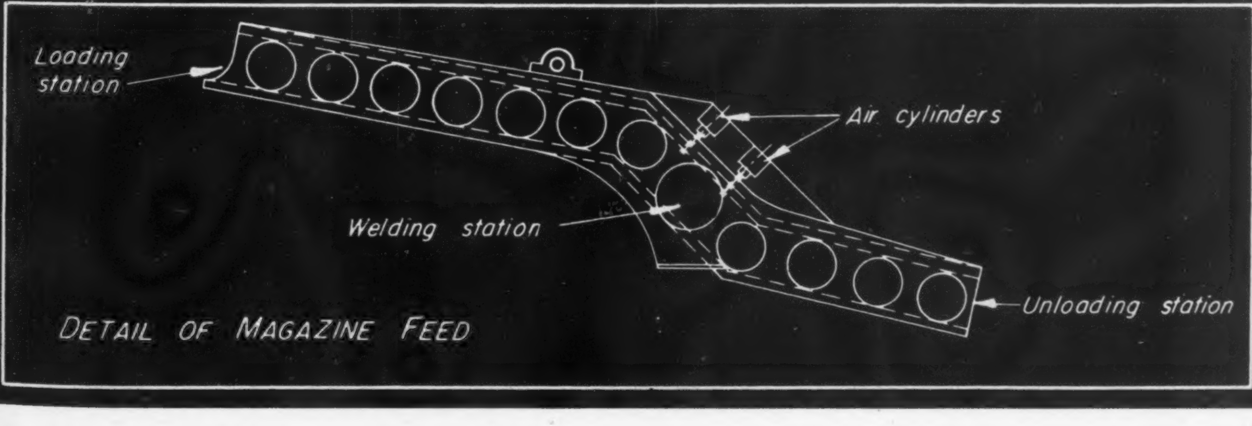
In operation, a wheel dropping into welding position initiates actuation of the air cylinder located at the bottom of the machine. The toggle mechanism, connected to the air cylinder and gun mounting plates, provides smooth and fast



SPOT WELDER TOGGLE FEED

backup pressure for the electrode guns. These welding guns are spring-loaded and can be adjusted individually for the proper weld pressure by varying the spring tension. The air cylinders mounted on the magazine feed locate and release the wheels as they are rolled down the chute of the inclined magazine.

Overload on the power supply is avoided by dividing the complete weld time into two firings, four spot welds with each firing. When the weld cycle is completed, the electrode guns retract and the wheels roll down through the machine to drop onto a belt conveyor which loads them into a bin. Manufacturer: Sciaky Bros. Inc., Chicago 38.



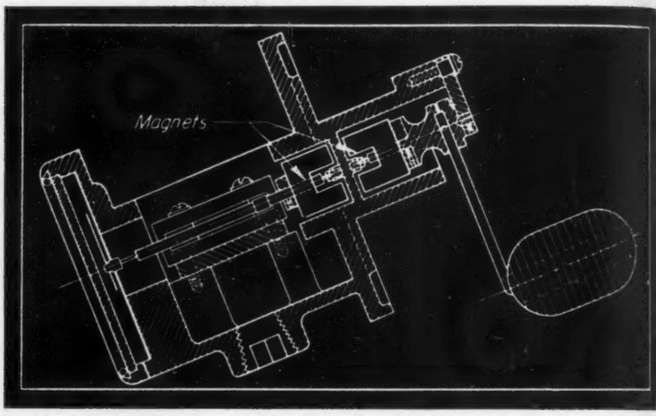
DETAIL OF MAGAZINE FEED

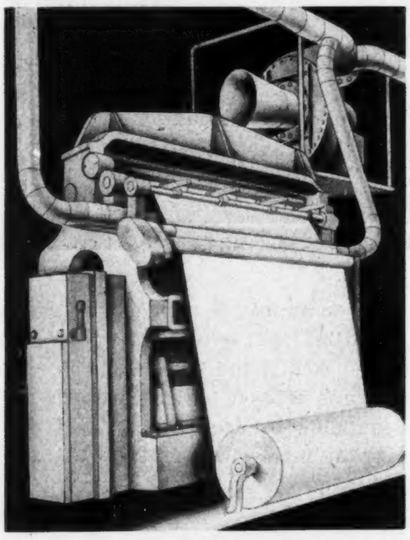
Applications

of engineering parts, materials and processes

Magnetic Coupling

LEAKPROOF coupling is provided magnetically in the liquid-level gage, right, made by the Boston Auto Gage Co. Used to indicate oil level in a transformer, the gage has a float which is positioned inside the oil tank and coupled to an Alnico magnet in the gage. Second magnet, coupled to the instrument needle, is separated from the first by an oil-tight aluminum diaphragm. Movement of the float is transmitted to the needle by the powerful magnetic flux set up between the two magnets.



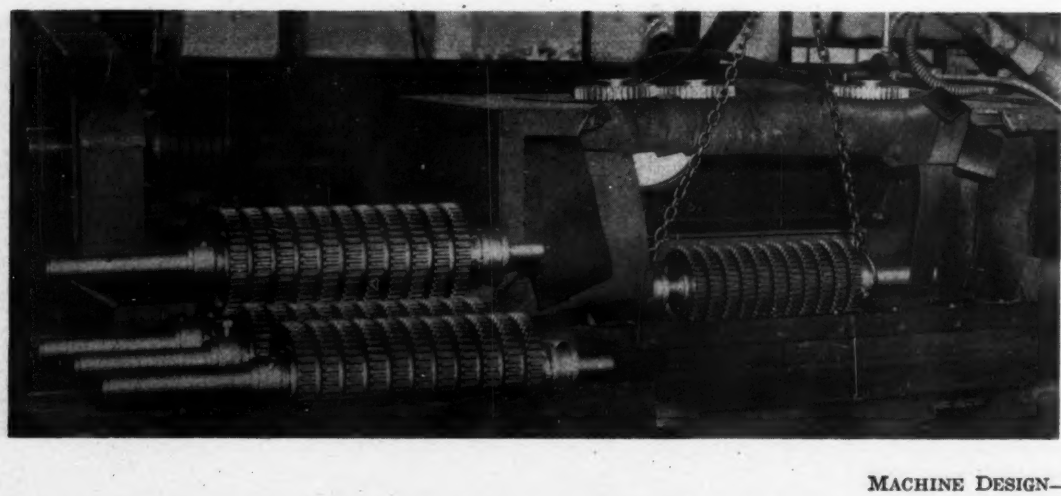


Removes Trim Pneumatically

TRIMMINGS from paper-towel trimming machine, left, are removed pneumatically, obviating large waste bins and saving valuable space and labor. The trim is removed from each end of the toweling by 28-inch vacuum created by a Sturtevant compressor, and ejected to waste bin.

Shot-Peened Gears

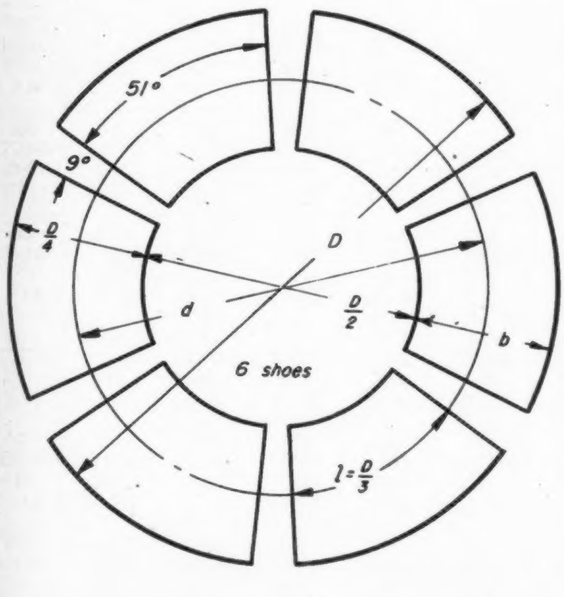
FATIGUE-LIFE increase of 1500 per cent has been realized by shot peening of truck gears. As illustrated below, the gears are peened in clusters in an automatic Wheelabrator machine. Impact of the high-velocity shot cold-works the surface of the gear teeth, placing the surface metal in residual compression and the underlying fibers in tension.



Load Capacity and Friction of Pivoted-Shoe Bearings

By H. A. S. Howarth
Bearing Engineer
Philadelphia, Pa.

Part I—Thrust Bearings



$$A_s = \frac{D^2}{12}$$

$$p_o = \frac{0.2705\,\mu\,vd}{h_o^2}$$

$$h_o = (0.3 \times 10^{-16} vd)^{3/8}$$

$$H_s = 1.465\mu \times 10^{-2} \times \frac{A_s v^2}{h_o}$$

Fig. 1—Proportions of 6-shoe thrust bearing, with formulas for area per shoe, average film pressure, minimum film thickness, and friction horsepower per shoe

PIVOTED-SHOE bearings are applicable to straight-line motion, as in crossheads, and to rotary motion, as in journal and thrust bearings. For rotary motion they may be fitted to any surface of revolution—flat, cylindrical, conical, or spherical. This data sheet is concerned with pivoted-shoe thrust bearings operating against flat thrust collars. Formulas and tables are presented for load capacity and friction characteristics of six and eight-shoe bearings. Similar tables will be published in next month's data sheet for pivoted-shoe journal bearings.

Proportions of six and eight-shoe bearing pads are shown in *Figs.* 1 and 2. Inside diameter usually is one-half the outside, making the mean diameter three-fourths of the outside. The standard sum of the face angles is, as shown, equal to 306 degrees, the remaining 54 degrees being equally distributed between the pads for oil channels.

LOAD CAPACITY: The fundamental relationship between variables for straight-line motion of pivoted shoes carrying a load upon flat wedge films of lubricant, without metallic contact, is given by the equation

$$h_o^2 = \frac{1.92\,\mu\,vlL_1}{p_o} \quad (1)$$

where the symbols have the meanings given in the Nomenclature. The equation assumes the creation of a film shape capable of carrying the greatest load for a given minimum film thickness, h_o. Under this condition the mean film thickness is equal to 1.594 h_o. The factor L_1, called the side-leakage correction factor for load, varies with shoe-face proportions.

For the six-shoe bearing, *Fig.* 1, $l/b = 4/3$, the

ENGINEERING DATA SHEET

TABLE I. Load Capacity and Friction Horsepower of 51° Thrust Shoes (Fig. 1)

For 6-shoe bearing, total thrust $= 6\, A_s\, p_o$
total friction hp $= 6 H_s$

D (in.)	d (in.)	A_s (in.²)	V_d (ft/sec)	5	10	20	40	60	80	100	120	140
6	4½	3	p_o (*psi*)	156	186	221	263	291	313	331	346	359
			h_o (*in.*)	.000364	.000472	.000612	.000794	.000924	.00103	.00112	.00120	.00127
			N_d (*rpm*)	254	509	1018	2036	3053	4071	5089	6107	7124
			H_s (*hp*)	.01025	.0317	.0977	.3013	.5825	.929	1.335	1.794	2.305
12	9	12	p_o (*psi*)	186	221	263	313	346	372	393	412	428
			h_o (*in.*)	.000472	.000612	.000794	.00103	.00120	.00133	.00145	.00155	.00165
			N_d (*rpm*)	127	254	509	1018	1526	2036	2544	3053	3562
			H_s (*hp*)	.0317	.0977	.3010	.9290	1.794	2.880	4.125	5.555	7.100
18	13½	27	p_o (*psi*)	205	244	291	346	383	412	434	456	473
			h_o (*in.*)	.000549	.000713	.000924	.00120	.00140	.00155	.00169	.00181	.00192
			N_d (*rpm*)	85	170	339	679	1018	1357	1696	2036	2375
			H_s (*hp*)	.06125	.1887	.5830	1.795	3.460	5.555	7.966	10.70	13.74
24	18	48	p_o (*psi*)	221	263	313	371	411	441	467	490	513
			h_o (*in.*)	.000612	.000794	.00103	.00133	.00155	.00173	.00188	.00202	.00214
			N_d (*rpm*)	64	127	254	509	763	1018	1272	1527	1781
			H_s (*hp*)	.0977	.3010	.9300	2.877	5.555	8.850	12.72	17.05	21.9
30	22½	75	p_o (*psi*)	233	278	331	393	434	468	495	518	537
			h_o (*in.*)	.000665	.000863	.00112	.00145	.00169	.00188	.00205	.00219	.00232
			N_d (*rpm*)	51	102	204	407	611	814	1018	1221	1425
			H_s (*hp*)	.1405	.4330	1.335	4.125	7.966	12.73	18.24	24.60	31.60
36	27	108	p_o (*psi*)	244	291	346	411	455	490	518	542	563
			h_o (*in.*)	.000713	.000924	.00120	.00155	.00181	.00202	.00219	.00235	.00249
			N_d (*rpm*)	42.3	85	170	339	509	679	848	1018	1187
			H_s (*hp*)	.1887	.5825	1.795	5.555	10.70	17.05	24.60	33.0	42.35
42	31½	147	p_o (*psi*)	254	302	359	428	473	511	537	564	584
			h_o (*in.*)	.000755	.000979	.00127	.00165	.00192	.00214	.00232	.00249	.00263
			N_d (*rpm*)	36.4	73	145	291	436	582	727	872	1018
			H_s (*hp*)	.2427	.7475	2.308	7.105	13.74	21.90	31.60	42.37	54.6
48	36	192	p_o (*psi*)	263	313	372	441	490	526	555	583	604
			h_o (*in.*)	.000794	.00103	.00133	.00173	.00202	.00224	.00244	.00261	.00277
			N_d (*rpm*)	31.8	64	127	254	382	509	636	763	890
			H_s (*hp*)	.3012	.9300	2.880	8.850	17.05	27.35	39.22	52.83	67.74
54	40½	243	p_o (*psi*)	270	322	383	455	504	542	572	600	622
			h_o (*in.*)	.000830	.00108	.00140	.00181	.00211	.00235	.00255	.00273	.00289
			N_d (*rpm*)	28.3	57	113	226	339	452	565	679	792
			H_s (*hp*)	.3650	1.120	3.460	10.70	20.68	33.0	47.5	63.8	82.1
60	45	300	p_o (*psi*)	278	331	393	467	518	555	587	616	639
			h_o (*in.*)	.000863	.00112	.00145	.00188	.00219	.00244	.00265	.00284	.00301
			N_d (*rpm*)	25.5	51	102	204	305	407	509	611	712
			H_s (*hp*)	.4330	1.334	4.125	12.73	24.60	39.22	56.4	75.8	97.3
66	49½	363	p_o (*psi*)	285	338	403	478	531	569	602	631	654
			h_o (*in.*)	.000894	.00116	.00150	.00195	.00227	.00253	.00275	.00295	.00312
			N_d (*rpm*)	23.1	46.3	92	185	278	370	463	555	647
			H_s (*hp*)	.5060	1.557	4.825	14.83	28.68	45.76	65.8	88.35	113.7
72	54	432	p_o (*psi*)	291	346	412	490	542	583	615	645	670
			h_o (*in.*)	.000924	.00120	.00155	.00202	.00235	.00261	.00284	.00304	.00322
			N_d (*rpm*)	21.2	42.3	85	170	254	339	424	509	594
			H_s (*hp*)	.5830	1.795	5.555	17.05	33.00	52.83	75.8	102.0	131.0
78	58½	507	p_o (*psi*)	297	353	420	500	553	593	626	658	682
			h_o (*in.*)	.000952	.00123	.00160	.00208	.00242	.00269	.00293	.00314	.00332
			N_d (*rpm*)	19.6	39.2	78	156	235	313	392	470	548
			H_s (*hp*)	.6630	2.053	6.320	19.44	37.60	60.15	86.2	115.8	149.2
84	63	588	p_o (*psi*)	302	359	428	511	563	604	639	670	695
			h_o (*in.*)	.000979	.00127	.00165	.00214	.00249	.00277	.00301	.00322	.00342
			N_d (*rpm*)	18.2	36.3	73	145	218	291	364	436	509
			H_s (*hp*)	.7490	2.307	7.105	21.90	42.35	67.74	97.4	131.1	168.0

Tabular values are based on $\mu = 3.4 \times 10^{-6}$ lb-sec per sq in. (Reyns), equivalent to 0.2345 poise or 23.45 centipoise.

When loading shoe higher than tabular value of p_o, increase viscosity in same ratio to maintain film thickness. Horsepower loss will increase in same ratio.

TABLE II. Load Capacity and Friction Horsepower of 38¼° Thrust Shoes (Fig. 2)

For 8-shoe bearing, total thrust $= 8A_s\,p_o$
total friction hp $= 8H_s$

D (in.)	d (in.)	A_s (in.^{2})	V_d (ft/sec)	5	10	20	40	60	80	100	120	140
6	4½	2¼	p_o (psi)	180	214	255	303	336	361	382	399	414
			h_o (in.)	.000346	.000448	.000582	.000754	.000878	.000980	.00106	.00114	.00121
			N_d (rpm)	254	509	1018	2036	3053	4071	5089	6107	7124
			H_s (hp)	.00825	.0256	.0787	.243	.470	.748	1.075	1.446	1.855
12	9	9	p_o (psi)	214	255	303	361	399	429	453	475	493
			h_o (in.)	.000448	.000582	.000754	.000980	.00114	.00126	.00138	.00147	.00157
			N_d (rpm)	127	254	509	1018	1526	2036	2544	3053	3562
			H_s (hp)	.0256	.0787	.243	.748	1.446	2.320	3.325	4.476	5.720
18	13½	20¼	p_o (psi)	236	281	336	399	442	475	500	525	545
			h_o (in.)	.000522	.000677	.000878	.00114	.00133	.00147	.00161	.00172	.00182
			N_d (rpm)	85	170	339	679	1018	1357	1696	2036	2375
			H_s (hp)	.0493	.152	.470	1.446	2.788	4.475	6.420	8.62	11.08
24	18	36	p_o (psi)	255	303	361	428	474	508	538	565	592
			h_o (in.)	.000582	.000754	.000980	.00126	.00147	.00164	.00179	.00192	.00203
			N_d (rpm)	64	127	254	509	763	1018	1272	1527	1781
			H_s (hp)	.0787	.243	.750	2.319	4.476	7.130	10.25	13.74	17.65
30	22½	56¼	p_o (psi)	269	321	382	453	500	539	571	597	619
			h_o (in.)	.000632	.000820	.00106	.00138	.00161	.00179	.00195	.00208	.00220
			N_d (rpm)	51	102	204	407	611	814	1018	1221	1425
			H_s (hp)	.1132	.349	1.075	3.323	6.420	10.26	14.70	19.83	25.46
36	27	81	p_o (psi)	281	336	399	474	525	565	597	625	649
			h_o (in.)	.000678	.000878	.00114	.00147	.00172	.00192	.00208	.00223	.00237
			N_d (rpm)	42.3	85	170	339	509	679	848	1018	1187
			H_s (hp)	.152	.4695	1.446	4.476	8.62	13.74	19.82	26.60	34.12
42	31½	110¼	p_o (psi)	293	348	414	493	545	589	619	650	673
			h_o (in)	.000718	.000930	.00121	.00157	.00182	.00204	.00220	.00237	.00250
			N_d (rpm)	36.4	73	145	291	436	582	727	872	1018
			H_s (hp)	.1952	.603	1.860	5.720	11.08	17.65	25.47	34.15	44.00
48	36	144	p_o (psi)	303	361	429	508	565	606	640	672	696
			h_o (in.)	.000754	.000980	.00126	.00164	.00192	.00213	.00232	.00248	.00263
			N_d (rpm)	31.8	64	127	254	382	509	636	763	890
			H_s (hp)	.2426	.749	2.320	7.130	13.74	21.07	31.60	42.60	54.60
54	40½	182¼	p_o (psi)	311	371	442	525	581	625	659	692	717
			h_o (in.)	.000789	.00103	.00133	.00172	.00200	.00223	.00242	.00259	.00275
			N_d (rpm)	28.3	57	113	226	339	452	565	679	792
			H_s (hp)	.294	.902	2.788	8.62	16.67	26.60	38.25	51.45	66.20
60	45	225	p_o (psi)	321	382	453	538	597	640	677	710	736
			h_o (in.)	.000820	.00106	.00138	.00179	.00208	.00232	.00252	.00270	.00285
			N_d (rpm)	25.5	51	102	204	305	407	509	611	712
			H_s (hp)	.349	1.074	3.325	10.26	19.83	31.60	45.50	61.20	78-50
66	49½	272¼	p_o (psi)	329	390	465	551	612	656	693	727	753
			h_o (in.)	.000850	.00110	.00143	.00185	.00216	.00240	.00261	.00280	.00296
			N_d (rpm)	23.1	46.3	92	185	278	370	463	555	647
			H_s (hp)	.4075	1.254	3.890	11.95	23.10	36.90	53.10	71.20	91.7
72	54	324	p_o (psi)	336	399	475	565	625	672	708	743	772
			h_o (in.)	.000878	.00114	.00147	.00192	.00223	.00248	.00270	.00289	.00306
			N_d (rpm)	21.2	42.3	85	170	254	339	424	509	594
			H_s (hp)	.470	1.446	4.476	13.74	26.60	42.60	61.20	82.20	105.5
78	58½	380¼	p_o (psi)	342	407	484	576	638	684	722	758	786
			h_o (in.)	.000905	.00117	.00152	.00198	.00230	.00256	.00278	.00298	.00316
			N_d (rpm)	19.6	39.2	78	156	235	313	392	470	548
			H_s (hp)	.534	1.654	5.090	15.66	30.30	48.50	69.50	93.20	120.2
84	63	441	p_o (psi)	348	414	493	589	649	696	737	772	801
			h_o (in.)	.000930	.00121	.00157	.00204	.00237	.00263	.00286	.00306	.00325
			N_d (rpm)	18.2	36.3	73	145	218	291	364	436	509
			H_s (hp)	.603	1.860	5.720	17.64	34.15	54.60	78.50	105.6	135.4

Tabular values are based on $\mu = 3.4 \times 10^{-6}$ lb-sec per sq in. (Reyns), equivalent to 0.2345 poise or 23. 45 centipoise.

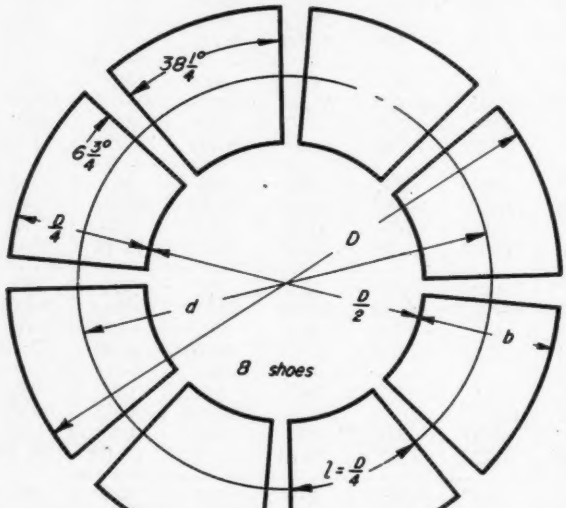
When loading shoe higher than tabular value of p_o, increase viscosity in same ratio to maintain film thickness. Horsepower loss will increase in same ratio.

ENGINEERING DATA SHEET

corresponding value of L_1 being 0.317, as determined by Kingsbury. Substituting this value in Equation 1, as well as the relation $l = 4d/9$, the equation for pressure, p_o, given on *Fig.* 1 results.

For the eight-shoe bearing, *Fig.* 2, $l/b = 1.00$, the value of L_1 is 0.437, and $l = d/3$. Equation 1 then assumes the form given in *Fig.* 2 for p_o.

FILM THICKNESS: Experience and engineering



$$A_s = \frac{D^2}{16}$$

$$p_o = \frac{0.28\,\mu\,vd}{h_o^2}$$

$$h_o = (0.2616 \times 10^{-10} vd)^{3/8}$$

$$H_s = 1.494\mu \times 10^{-2} \times \frac{A_s v^2}{h_o}$$

Fig. 2—Proportions of 8-shoe thrust bearing, with formulas for area per shoe, average film pressure, minimum film thickness, and friction horsepower per shoe

practice indicate that thinner films should be used for shoes of smaller area, other conditions being the same. A study of loading practice, applicable to a uniform series of similar, standard thrust bearing shoes for which $l/b = 4/3$, indicates the following empirical relation for minimum film thickness:

$$h_o = (0.675 \times 10^{-10} vl)^{3/8} \quad \ldots\ldots (2)$$

Using the relations $l = 4d/9$ for the 51-degree shoe and $l = d/3$ for the $38\frac{1}{4}$-degree shoe, results in the equations given for h_o in *Figs.* 1 and 2. As already indicated, the mean film thickness under the assumed conditions is 1.594 h_o.

FRICTION HORSEPOWER: Horsepower per shoe lost in friction is given by the equation

$$H_s = 1.646 \times 10^{-2} \times F_1 \frac{A_s v^2}{h_o} \quad \ldots\ldots (3)$$

Applying side-leakage correction factors $F_1 = 0.89$ for the 51-degree shoe and $F_1 = 0.908$ for the 38$\frac{1}{4}$-degree shoe results in the equations given for H_s in *Figs.* 1 and 2.

TABLES I and II present for selected bearing sizes and speeds the results of applying the equations in *Figs.* 1 and 2 with a coefficient of viscosity $\mu = 3.4 \times 10^{-6}$ lb-sec per sq in. If higher loading than the indicated value of p_o must be employed, the viscosity should be increased in the same ratio in order to maintain the film thickness. The horsepower, H_s, will be increased in the same ratio as the pressure and viscosity. Hence, the designer can load a bearing up to any desired pressure within the mechanical strength of the bearing elements, if he is careful to lubricate it with oil of the required viscosity range and to cool that oil so that it will have the desired mean viscosity at the mean operating temperature of the film.

EXAMPLE 1: To illustrate the relative performance of six and eight-shoe bearings, two 36-inch bearings operating at 20 ft per min mean velocity (170 rpm) will be compared. For the six-shoe bearing, TABLE I shows $p_o = 346$, $H_o = 0.00120$, and $H_s = 1.795$. The capacity therefore is $T = 6\ A_s p_o = 6 \times 108 \times 346 = 224{,}000$ lb and the friction horse power is $hp = 6H_s = 6 \times 1.795 = 10.77$. For the eight-shoe bearing, TABLE II shows $p_o = 399$, $h_o = 0.00114$, and $H_s = 1.446$. The capacity therefore is $T = 8A_s p_o = 8 \times 81 \times 399 = 258{,}000$ lb and the friction horsepower is $hp = 8H_s = 8 \times 1.446 = 11.57$. Thus, on a film 5 per cent thinner, the eight-shoe bearing carries 15 per cent higher load but absorbs 9½ per cent more horsepower.

EXAMPLE 2: To bring the capacity of the six-shoe bearing up to that of the eight-shoe in the foregoing example, the vicosity could be increased 15 per cent, the film thickness remaining the same. The horsepower would be increased to $1.15 \times 10.77 = 12.38$ compared with 11.57 for the eight-shoe bearing of equal capacity. Actually, this friction difference is insignificant in a bearing of this size.

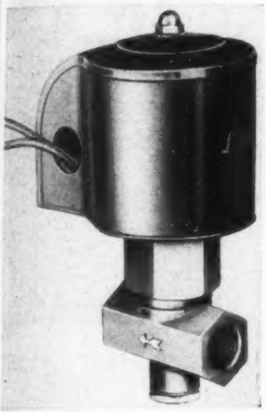
Nomenclature

D = Outside diameter of bearing, in.
d = Mean diameter of shoes = $3D/4$ in.
b = Radial width of shoe, in.
l = Mean circumferential length of shoe face, in.
v_d = Mean velocity, ft per sec
= $\pi dN_d/60$
N_d = Speed of revolution, rpm
A_s = Area per shoe, sq-in.
p_o = Average film pressure, psi
h_o = Minimum film thickness at diameter d, in.
μ = Coefficient of viscosity, lb-sec per in.³ (Reyns)
H_s = Friction per shoe, hp
L_1 = Side leakage factor for load
F_1 = Side leakage factor for friction

new parts and materials

For additional information on these new developments see Page 245

High-Pressure Solenoid Valve



Suitable for handling gas, water light oils and other noncorrosive fluids, new ½-inch high-pressure shut-off valve is capable of handling 1500 psi. It is of normally-closed design with coils wound for continuous service, although the solenoid functions only in the opening operation. Body is forged brass with renewable stainless steel seat; piston is stainless steel as are the core and disk. The valve is designed for use in continuous operation up to 200 cycles per minute for gases or 150 cycles per minute for fluids. Models are made for operation at 110, 220 or 440 volts and 25, 30, 50, or 60 cycles a-c. For d-c operation models are made for operation at 115 or 230 volts. Manufacturer: Automatic Switch Co., Orange, N. J.

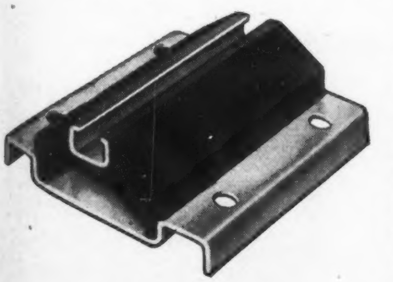
For further information circle MD 1 on Page 245

Over-Center Friction Clutches

Line of over-center friction clutches is made in ratings from 0.5 to 1.7 hp per 100 rpm. Adaptable for use in a wide variety of installations, the units are made in two basic designs which may be widely varied by small modifications. Manufacturer: Morse Chain Co., 7601 Central Ave., Detroit 8.

For further information circle MD 2 on Page 245

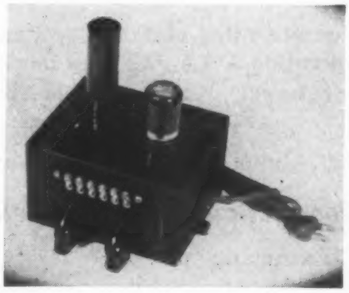
Medium-Frequency Rubber Vibration Mount



Rubber vibration mount for vibrational frequencies as low as 600 cpm is suitable for use with pumps, compressors, air conditioners, motor-generator sets, etc. Mount consists of two metal channels between which is positioned the rubber cushion. Lower channel has holes for bolting down while upper channel has lips to retain head of bolt used to secure machine or part being mounted. Overall height is 1½ inches, deflection is ¼-inch. Units, known as Chan-L-Mounts are made in a full range of sizes for light or medium-weight mounting. Manufacturer: Lord Mfg. Co., Erie, Pa.

For further information circle MD 3 on Page 245

Repeat-Cycle Timer



Control device for actuating electrical circuits through predetermined time intervals has range of 0.1-second to 4 minutes. Operating from 115-volt 60-cycle power, the unit has relay contacts arranged in combinations up to double-pole double-throw. Each contact is rated 10 amperes at 115 volts. Timer provides independently variable on and off intervals with complete adjustability within the range. Wide variations in line voltage are said to have only a minor effect on the accuracy of the timing intervals. Unit measures 3 by 4 by 5 inches. Manufacturer: G. C. Wilson & Co., 2 N. Passaic Ave., Chatham, N. J.

For further information circle MD 4 on Page 245

Reusable Lock Nut

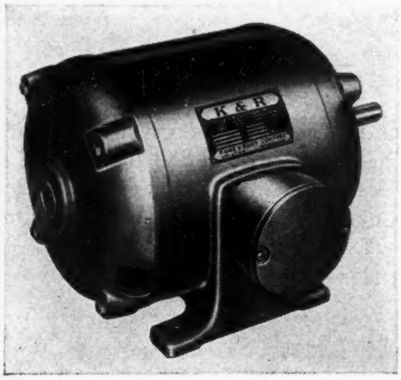
Either fiber or metal washers may be used as the replaceable locking units of this new lock nut. The nut may, therefore, be used where resistance to heat is essential. Full holding strength of the nut may be restored after use by replacing the locking units, an operation which requires no tools. Manufacturer: Swallow Airplane Co., Wichita, Kansas.

For further information circle MD 5 on Page 245

Heavy-Duty Selenium Rectifiers

Squirrel-cage three-phase, 60-cycle, 220 or 440-volt induction motors are rated 40 C continuous duty and are capable of being operated at rated voltage on 50-

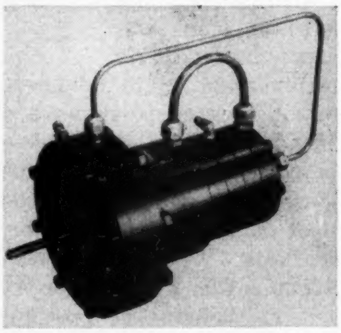
cycle current with a standard 50 C temperature rise. Features include sealed ball bearings, pressure-cast rotor with aluminum bars and end rings, and integrally cast fan blades. Models for 1750 rpm opera-



tion are rated at 1, 1.5, 2, 3 and 5 hp. For 1150 rpm operation 1, 1.5 and 2 hp models are available. Manufacturer: Kurz and Root Co., Appleton, Wisconsin.

For further information circle MD 6 on Page 245

Pneumatic Positioning Device



Pneumatic power unit known as the Micropositioner is capable of precisely positioning a lever within a few thousandths of an inch over a range of 0—0.5-inch. Operating on 60 psi air pressure the unit is capable of exerting considerable force and works directly without use of mechanical linkages. Typical applications include governor-gear and injection-nozzle positioning. Manufacturer: Hagan Corp., 323 4th Ave., Pittsburgh 30.

For further information circle MD 7 on Page 245

Pressed-Steel Sheaves

Line of steel V-belt sheaves has a demountable hub permitting single, dual or step-pulley arrangement

to fit practically all applications. The sheaves are manufactured in A and B sections and with single or double grooves from 4 to 15 inches in diameter. Manufacturer: Howry-Berg Steel and Iron Works, 2949 N. Speer Blvd., Denver 11.

For further information circle MD 8 on Page 245

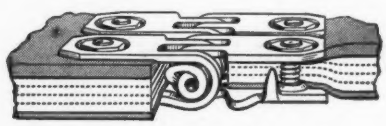
Heavy-Duty Selenium Rectifiers

Rated 12 amperes in a single-phase bridge circuit, selenium rectifier elements have a leakage current less than 1 ma per sq cm at 25 rms reverse voltage. These type H cells feature interlocking assembly of rectifier components, conservatively rated terminals and special moisture proofing. They measure 6¼ by 7¼ inches and have a ⅜-16 mounting stud. Manufacturer: International Rectifier Corp., 6809 S. Victoria Ave., Los Angeles 43.

For further information circle MD 9 on Page 245

Conveyor-Belt Fastener

Separable conveyor-belt fastener consists of a series of U-shaped galvanized plates bolted to each end of the belt and joined together with a flexible hinge pin. It is made in one size for belts ⅜ to ½-



inch thick. Hinge pin is tightly-wound spring steel which engages concave arc cut in belt end and bends easily with troughing of the belt. Manufacturer: Flexible Steel Lacing Co., 4607 Lexington St., Chicago 44.

For further information circle MD 10 on Page 245

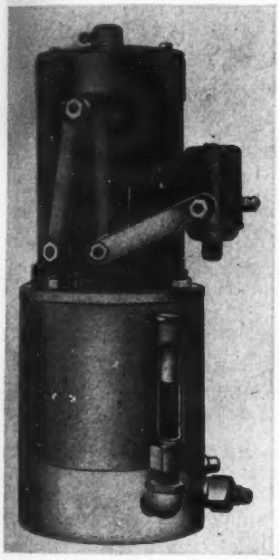
Light-weight High-Speed Motors

Featuring light weight, small size and fast starting and stopping characteristics, line of drag-cup motors is particularly suitable for use with control mechanisms. Rated 0.32 to 0.41 oz-in. stall torque, the mo-

tors weigh 7.6 pounds, and measure 1.922 inches long and 1.719 inches in diameter. Two standard types are available. One runs at 3000 rpm using 115-volts, 60-cycle current; the other runs at 5000 rpm on 115-volt, 400-cycle power. Since the motors can be operated continuously under stall conditions, they are suitable for numerous applications such as backlash elimination in gear trains. They are also recommended for use as low-torque dynamometers and as variable-speed motors. Manufacturer: Kollsman Instrument Div., Square D Co., 80-08 45th Ave., Elmhurst, N. Y.

For further information circle MD 11 on Page 245

Hydraulic Power Unit

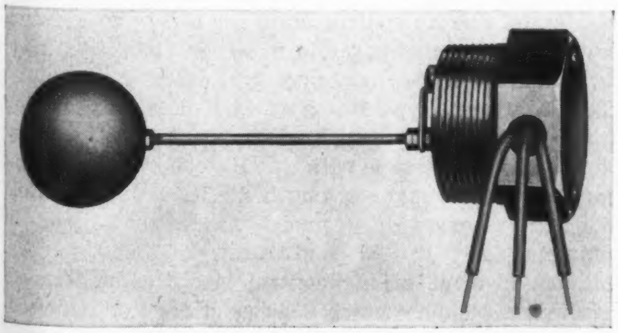


Pressures up to 2000 psi at flows up to 4 gpm are produced by the model 1100 Pack O' Power hydraulic power unit. Consisting of the electric motor, pump, reservoir valves and flow regulator, the unit is adaptable for use with single-cylinder, gravity, or spring-return ram systems as well as other hydraulic applications requiring up to 1½ hp intermittent-duty rating. The assembly measures 5¾ inches in diameter and 14 inches high and may be mounted either vertically or horizontally. All valves are externally assembled for ease of service. Manufacturer: Jerome Hydraulics Co., 60 Ocean Ave., Lynbrook, N. Y.

For further information circle MD 12 on Page 245

Magnetic Proximity Switch

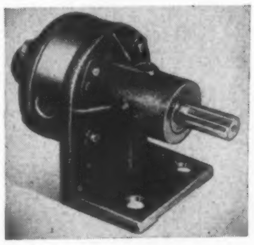
Operating by means of the repulsion of like poles of permanent magnets, new snap-action switch can be actuated without actual physical contact being made. Housed in a simple metal cannister 21/32-inch in diameter, the switch is available in a number of standard and custom-built mounting styles with



single-pole double-throw action. Switch is rated to handle a-c motors up to ¼-hp in size and has withstood 2 million operations under load without failure. Manufacturer: Magneswitch Inc., 4215 S. Western Blvd., Chicago 9.

For further information circle MD 13 on Page 245

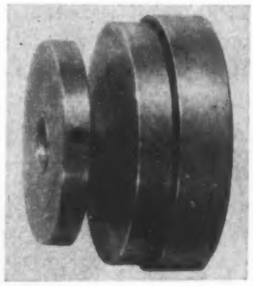
Rotary Pumps



Operating on a new rotary pump principle, the series C-175 pump has a high volumetric efficiency and low power requirements. Ordinary wear does not reduce the pump capacity or pressure. Standard unit will handle lubricating oils, hydraulic oils, etc. at capacities from ½ to 4 gpm at 125 psi. It can be run in either direction direct coupled without modification. Foot, flange or sump models are available. Manufacturer: Ellipse Corp., 4140 N. Kedzie Ave., Chicago 18.

For further information circle MD 14 on Page 245

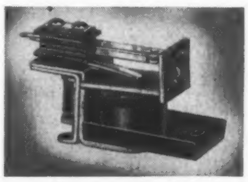
Automatic V-Belt Clutch



Variable pitch diameter clutch, for use with V-belts, uses the belt as the nonmetallic portion of the clutch. Life is thereby increased and the only wearing portion of the assembly is easily replaced. Automatic factory setting causes the pulley diameter to expand at preselected speeds; normally, the clutch will engage at 1400 rpm under no load and 1700 rpm under full load. Units are available in the pitch diameter range 2 to 3⅜ inches maximum and 1⅝ to 1⅞ inches minimum. Manufacturer: W. S. K. Inc., Donovan Bldg., Detroit 1.

For further information circle MD 15 on Page 245

Alternating-Current Relay

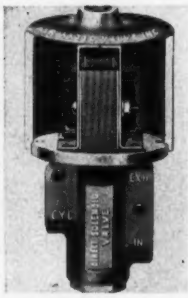


Rated 12 amp at 60-cycle voltages up to 230, Series 100-U relays are Underwriter Laboratories approved. The units are open type with coils available for 6, 12, 24, 115 and 230 volts. Six contact combinations are made. Type 100-U-A is single-pole, single-throw, normally-open; 100-U-B is single-pole, single-throw, normally-closed; 100-U-C is of the single-throw, double-throw type. Double-pole relays include: Type

100-U-E, which is single-throw normally-open; 100-U-F, single-throw, normally-closed, and 100-U-G of the double-throw type. Manufacturer: Guardian Electric Mfg. Co., 1601 W. Walnut St., Chicago 12.

For further information circle MD 16 on Page 245

Three-Way Solenoid-Controlled Valve

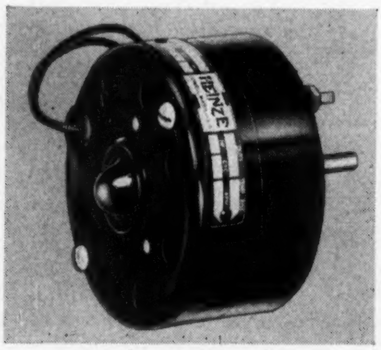


Noncorrosive, 3-way, direct-operating solenoid valve can be mounted in any position and subjected to continuous operation without harm to valve or solenoid. Unit is made in four standard pipe sizes—$\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$ and $\frac{3}{4}$-inch—and internal parts are machined of corrosion-resistant material. The solenoid is rated 1.42 amperes inrush and 0.22 amperes holding at 110 volts, 60 cycles. Manufacturer: Air-matic Valve Inc., 1643 E. 40th St., Cleveland.

For further information circle MD 17 on Page 245

Shaded-Pole Induction Motor

Type Z shaded-pole induction motor is made in ratings from 1/100 to 1/40 hp and has free speed of 1700 rpm. Measuring $3\frac{1}{4}$ inches in diameter, the motor is a low-cost unit having a pressed steel case. It is furnished with ventilated or nonventilated case and with or without junction box. Unit has single



or double-shaft extension, centerless-ground and hardened steel shaft and oilless self-aligning bearings. Thrust bearings are provided for vertical operation. Manufacturer: The Heintze Electric Co., Lowell, Mass.

For further information circle MD 18 on Page 245

Electric Time Switch

Rated 35 amperes at 115 and 230 volts, synchronous-motor operated type T-47 timer has a single-pole single-throw switch with large, silver, snap-action contacts. It is designed for on and off timing of a single circuit and will perform one on and one off operation during any 24-hour period and continue to do so indefinitely. Operation of the unit can be manual or automatic. Adjustable switch-tripping clamps permanently attached to the timer dial are used for setting the switch for automatic operation. They allow a minimum setting of five minutes and a maximum setting of 22 hours between on and off opera-

tions. Manual operation of either setting is possible independently of automatic settings already on the dial. Manufacturer: General Electric Co., Schenectady 5, N. Y.

For further information circle MD 19 on Page 245

Aluminum Pressure Castings

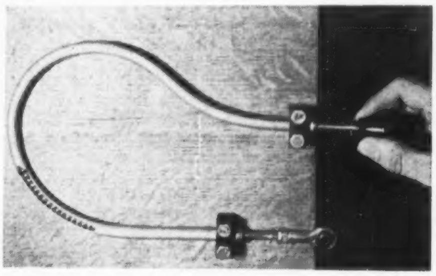
Pressure-molded aluminum-base alloy castings have high ultimate strength and ductility. Combining many of the desirable properties of die castings, forgings and permanent-mold castings, the parts provide wide latitude in design. Typical physical properties of the castings include: Ultimate strength of 47,000 psi, 12 ft-lb Charpy impact and 10 per cent elongation in 2 inches. Manufacturer: Lukens Aluminum Corp., P. O. Box 302, Dayton, Ohio.

For further information circle MD 20 on Page 245

Cable-Control Unit

Manual remote control units for use in conjunction with mechanical, hydraulic or other devices is made in three types: Light, heavy and extra- heavy duty. The light-duty type has a $\frac{3}{8}$-inch diameter housing and a load range of 1250 pounds ultimate compression. Heavy-duty type with a 7/16-inch diameter housing has an ultimate strength of 1650 pounds while the extra-heavy duty model measures $\frac{1}{2}$-inch in diameter and has a load range of 3050 pounds. Moving element of the control is a flexible, tinned, aircraft cable over which a series of steel or stainless-

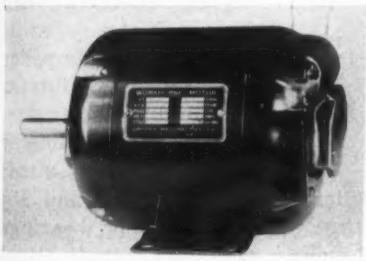
steel spherical shells are strung. Construction allows a normal bend radius of 2 inches with ¾-inch bends possible under certain conditions. Housings are 24-ST or 52-SO aluminum; all other aluminum parts are



24-ST. Stainless-steel control parts for high-temperature operation are also available. Manufacturer: Southwest Products Co., Pasadena, Calif.

For further information circle MD 21 on Page 245

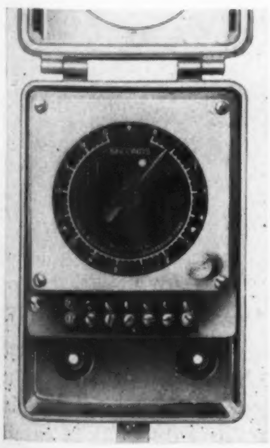
Single-Phase Motor



Capacitor-type, single-phase, ½-hp motor named the Workhorse is said to be the lightest motor of its rating yet developed. Weighing 29 pounds the unit utilizes aluminum for end brackets and has sheet-steel case and welded-steel frame. Cast-aluminum rotor is made by a centrifugal casting process. The motor operates on 115/230 volts; the 2-pole model rotating 3520 rpm, the 4-pole at 1760 rpm. Starting torque is 220 per cent and motor will withstand a 25 per cent overload indefinitely. Manufacturer: Crozier Machine Tool Co., Hawthorne, Calif.

For further information circle MD 22 on Page 245

Adjustable Electric Pulse Timer

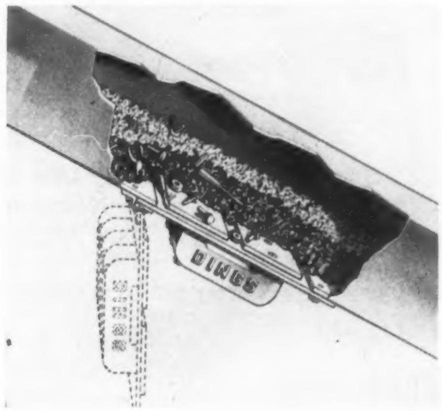


Electric pulses provided by the type V pulse timer may be used to initiate operations of automatic machinery in accordance with a repeated time cycle. Twelve ranges, varying from 15 seconds to 24 hours, are available and the length of the cycle may be changed within the range of the dial provided. Pulse time is controlled by a cam mechanism; a pointer indicating the time setting for the total time cycle and controling the interval between pulses produced by a single-pole, double-throw switch. Pulse time ranges from 0.5 second minimum to 12.5 hours maximum. Switch contact ratings are up to 1200 watts. Manufacturer: R. W. Cramer Co., Centerbrook, Conn.

For further information circle MD 23 on Page 245

Permanent Magnet Separators

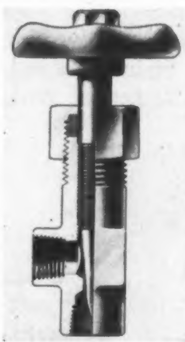
Line of magnetic separators for the removal of tramp iron from materials traveling in chutes consits of a series of C-shaped Alnico bars. The magnets, named Perma-Plates, are mounted on steel plates which are secured to an aluminum frame. As-



sembly is hinge mounted in place and can be swung out of position for cleaning. Standard units are made in a range of sizes from 4 to 72 inches wide in increments of 2 inches. Manufacturer: Dings Magnetic Separator Co., 4740 W. McGeogh Ave., Milwaukee 14.

For further information circle MD 24 on Page 245

Precision Needle Valves



Forty threads per inch in a class 3 fit are used on the stems of the Bulldog needle valves, facilitating fine adjustment. Made in ⅛ and ¼-inch sizes, valves have stainless-steel stems and bar-stock bodies and are guaranteed for water, gas or oil service at 500 psi. Units are designed to have the longest practicable needle to provide the most delicate flow control. Manufacturer: Carpenter Mfg. Corp., 9523 Detroit Ave., Cleveland 2.

For further information circle MD 25 on Page 245

Leak-Proof Locking Fasteners

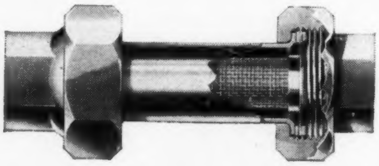
Available in either bolt, screw or stud form, Lok-Thred fasteners form a seal that liquids under pressure are not able to penetrate. With the positive

sealing action, bosses and blind tapping are unnecessary. Recent test, for example, on sample made to commercial tolerances withstood hydrostatic pressure of 3000 psi. Manufacturer: The National Screw & Mfg. Co., 2440 E. 75th St., Cleveland 4.

For further information circle MD 26 on Page 245

Fluid Strainers

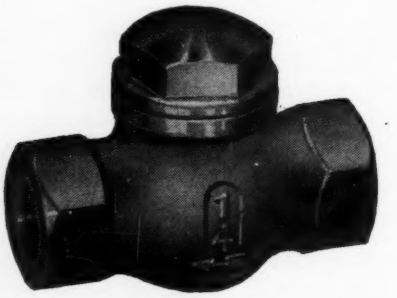
Designed for incorporation in piping systems, the Straitflo strainer is suitable for use with water, steam, oil, gas or air. It allows straight uninterrupted flow, creating a minimum of turbulence, and is readily



cleaned. Couplings are bronze, body-tube is copper and the screen is Monel. Asbestos Neoprene is used for gasketing. Manufacturer: Hays Mfg. Co., 12th and Liberty Sts., Erie, Pa.

For further information circle MD 27 on Page 245

Spring Check Valves



Piston-operated, spring-loaded check valves, called the series 1000, are designed for use with air, water, oil or gas. They operate with a minimum of noise and provide positive nonleaking check. Cast from high-grade bronze, the valves are made in pipe sizes 1/8, 1/4, 3/8, 1/2 and 3/4-inch. Manufactorer: Pokorney Mfg. Co. 3117 Clybourn Ave., Chicago.

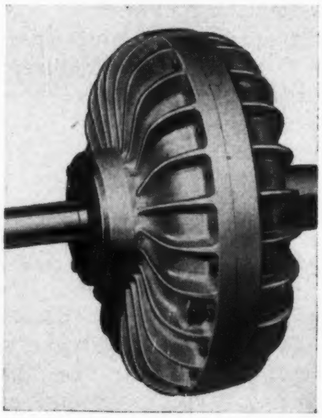
For further information circle MD 28 on Page 245

V-Belt Clutches

Line of V-belt clutches is suitable for transmitting from 5 to 10 hp. Feature of this line of Ball-Lok clutches is the use of free-turning bearings as idler pulleys. In the nondriving position, the pulley side walls are free of the belt and it rides entirely on the bearings. When clutch is engaged, the belt is gripped by the closing side walls and assumes the driven load. Shifting force is applied to the sheaves by means of shifter fork assemblies; no parts other than the shifting element are subject to rotating wear. Pulley diameter is 3¾-inches, length is 4⅛-inches. Shaft sizes accommodated are 1, 1⅛ and 1¼-inches. Manufacturer: V-Belt Clutch Co., 3757 Wilshire Blvd., Los Angeles 5.

For further information circle MD 29 on Page 245

Self-Contained Hydraulic Coupling

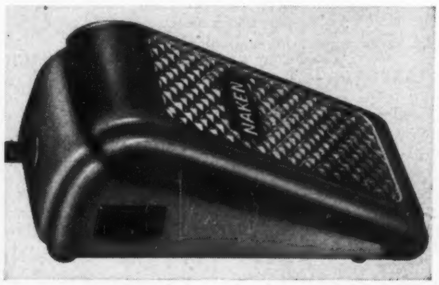


Fluidrive hydraulic coupling is a self-contained unit with single impeller element and runner, mounted on integrally fitted ball bearings. Straight radial vanes make possible operation in either direction with equal efficiency while low inertia of impeller and runner facilitates quick stops and reversing duty. Coupling is made in two sizes: 8½ inches for transmission of up to 5 hp and 9½ inches for up to 7½ hp. Use of shaft-end bearings in the coupling itself assures permanent shaft alignment, preventing shaft play and possible damage to the seals. Drive facilitates starting at no load and gradually accelerating the load to prescribed speed. Manufacturer: CraneVeyor Corp., 1240 S. Boyle Ave., Los Angeles.

For further information circle MD 30 on Page 245

Heavy-Duty Foot Switches

Cast-aluminum, heavy-duty foot switch is so constructed as to prevent dirt and chips from entering with normal usage. Two models of the switch are



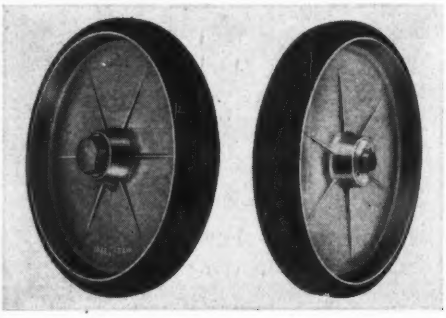
available. FS-40 has a standard cord and outlet and is rated 10 amperes at 125 volts; FS-50 has a cable clamp, rather than cord and outlet, and is suitable for use with BX or similar cable. It is rated 12 amperes at 125 volts. Both models are suitable

for use with either a-c or d-c in the range given. Either model is made in two types, momentary contact and double action. In the first, circuit is only made when the pedal is pressed, and brakes when pedal is released. In the second, circuit is made when pedal is depressed and opened on second pressure on pedal. Manufacturer: Naken Engineering & Mfg. Co., 25 N. Franklin St., Chicago 6.

For further information circle MD 31 on Page 245

Water-Tight Industrial Wheels

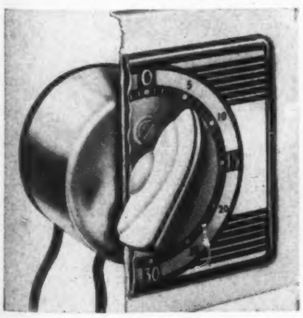
Made of high-strength, corrosion-resistant aluminum alloy, Aerol-Seal wheel has positive bearing seal allowing it to be submerged in water or washed with steam or detergents without deleterious effects. Wheel uses tapered roller bearings sealed by means of a combination of threaded retainer caps, Neoprene O-



rings and retainer spacers. Retainer spacers are so designed that no leakage can occur either while the wheel is functioning or idle. Solid rubber tire is molded onto the metal core. Five standard sizes are now available: 6, 8, 10, 14 and 20 inches. All sizes are made in styles for either inside or outside mounting. Manufacturer: Aerol Co., 1823 E. Washington Blvd., Los Angeles 21.

For further information circle MD 32 on Page 245

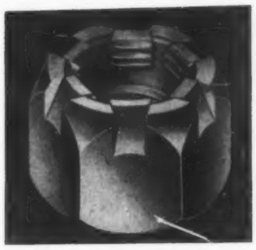
Spring-Wound Interval Timer



Suitable for use in controlling all types of machines and appliances, No. 1500 series minute-meters timer is made in timing ranges up to 120 minutes. Spring wound, the timer has switch rated 10 amperes at 200 volts. It is housed in a drawn metal case and is available in splash-proof models. Manufacturer: Lux Clock Mfg. Co., Waterbury, Conn.

For further information circle MD 33 on Page 245

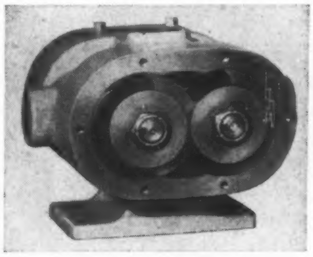
Self-Locking Nut



Having threaded sections which bear down on the bolt, the Hexlok nut will retain its position at any point despite shock and vibration. All metal, the nuts are suitable for aircraft use at temperatures up to 450 F. They are made in a complete range of sizes. Manufacturer: Boots Aircraft Nut Corp., Stamford, Conn.

For further information circle MD 34 on Page 245

Sludge Pump

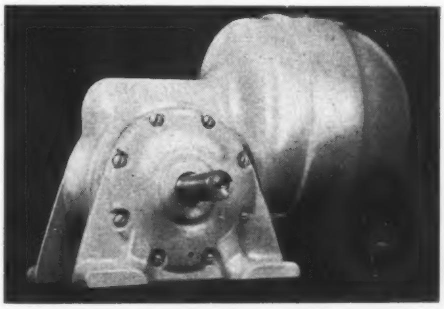


Suitable for the pumping of fluids containing large amounts of solids, the Thomson pump is made in capacities from 5 to 150 gpm. It will handle pulpy materials as well as liquids containing crystals or abrasives and is adaptable in design for use as a vacuum pump. Rotor is of an inverted bearing construction that places the bearing directly under the rotor load. Pump is quiet in operation, and delivers a constant volume. Dual ports, suiting the unit for right or left-hand assembly, are standard. Manufacturer: Thomson Pump Div., Waterous Co., St. Paul, Minn.

For further information circle MD 35 on Page 245

Light-Weight Gearmotors

Two models, foot and ring mounted, are available in a new line of light-weight gearmotors. Both the foot-mounted unit, series 400, and the ring-mounted series 500 unit are made in ¼, 1/3, ½, and ¾-hp sizes for operation on single, two or three-phase cur-



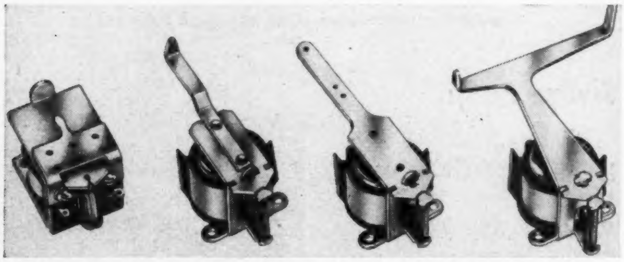
rent. Both models are of the general purpose, continuous-duty type with ball and tapered roller bearings. Gear housing and motor frame is one piece and reducer is of the single-reduction, right-angle wormgear type. Important feature of the design is

that the motor can be assembled in any one of four positions and the entire unit can be operated at almost any desired angle. Wide range of speeds is available. Manufacturer: Electra Motors Inc., 1110 N. Lemon St., Anaheim, Calif.

For further information circle MD 36 on Page 245

Relay Armatures

Variety of armature designs suitable for mechanical actuation is available on Guardian relays. Typical applications include: Mechanical interlocks for use



with associate relays, the armature serving as a locking device; and coin-control machine slug-rejector units, armatures having ears which engage the coin chute. Manufacturer: Dept. N.A.D. Guardian Electric Mfg. Co., 1601 W. Walnut St., Chicago 12.

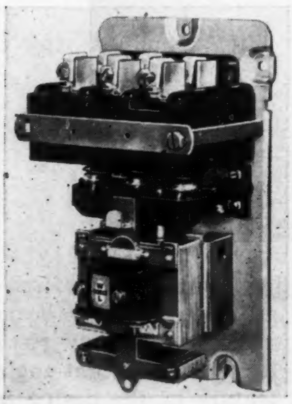
For further information circle MD 37 on Page 245

Low-Gloss Enamel

Synthetic heat-hardening low-gloss enamel is especially suitable for factory finishing of aluminum parts for outside exposure. Having a durability commensurate with other protective coatings used for the same application, the finish is spray-applied and fast baked, providing a hardness equal to that of refrigerator finishes. Resistant to weather, the material has withstood the 1500-hour salt-spray test as well as the 50-cycle heat and cold test. Manufacturer: Sherwin-Williams Co., 101 Prospect Ave., Cleveland 1.

For further information circle MD 38 on Page 245

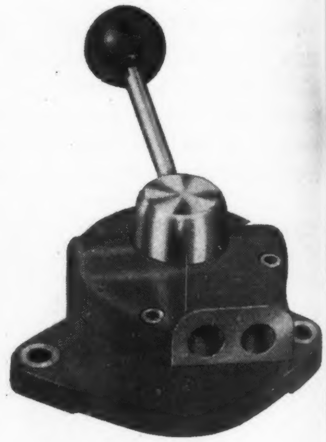
A-C Solenoid Contactors



Size 2, bulletin 4452, and size 3, bulletin 4453 a-c solenoid contactors are intended for use in a-c motor controllers. They are also suitable for use in resistive heating controls or for remote and automatic load switching purposes. Features of the contactors include unit construction, accessibility of parts, and use of built-in solderless connectors and large double-break silver contacts. All parts are mounted on a steel base plate having recommended NEMA dimensions. Size 2 and 3 units have maximum ratings of 25 and 50 hp, respectively, on 440-550 volt, 60-cycle, 3-phase current. Standard operating coils are available for 110, 220, 440 and 550 volt operation on 25, 50 or 60 cycles. Manufacturer: Ward Leonard Electric Co., Mount Vernon, N. Y.

For further information circle MD 39 on Page 245

Four-Way Pneumatic Valve

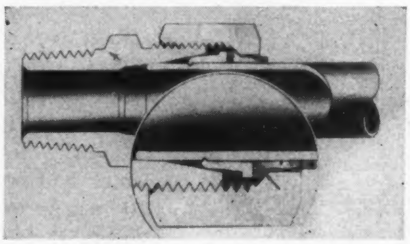


For use with pneumatic cylinders, Air-Miser valve has a by-pass port which allows half of the "power stroke" air of a double-acting cylinder to be used to return the piston. Valve by-passes air through an accumulator which stores half the exhausted air and uses it to return the piston to the starting position. Resultant air saving is thus 50 per cent. Auxiliary air port can be used in the event more air is needed to return piston, thus providing a four-way valve with the economy feature. Manufacturer: Knox Industries, Inc., 5538 Main St., Lexington, Mich.

For further information circle MD 40 on Page 245

Flareless High-Pressure Tube Fitting

Featuring the use of alloy steel grip sleeves, Fluid Fortress tube fittings absorb vibration and withstand hydraulic impact shock for the life of the installation. Fittings consist of three parts—body, tightening nut and steel sleeve. The chrome-molybdenum steel sleeve has a solid forward end and a slotted rearward end. The forward end is pressed into the tapered mouth of the connector body as the nut is tightened. This forces a sharp internal rib, which



will bite into the hardest tubing, into the tubewall, providing a fluid-tight seal between the sleeve and the tube. Simultaneously, metal-to-metal seals are formed between the sleeve and the body and the tube-

end and the body. Male and female fittings are made in sizes from $\frac{1}{4}$ to $1\frac{1}{2}$ inches in straight, tee and union types as well as 45 and 90-degree ells. Manufacturer: Flodar Corp., 331 Frankfort Ave., Cleveland 13.

For further information circle MD 41 on Page 245

Keying Relay

Designed for minimum space requirements, new keying relay will handle 5 amperes at 115 volts ac. It is made in normally-open, normally-closed, or transfer-contact styles, all contacts having self-wipinc action with follow for overtravel. Having a box-like rigid frame the relay will withstand 2000 *g* linear acceleration with less than a 2 per cent change in marginal operating current. Manufacturer: Signal Engineering & Mfg. Co., 161 W. 14th St., New York 11.

For further information circle MD 42 on Page 245

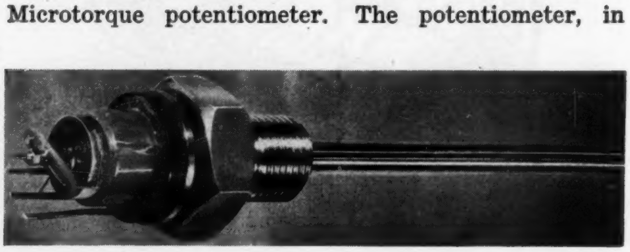
Low-Voltage Air Circuit Breaker

Designed for use on voltages 600 and below, the type AK-1 circuit breaker is made in two ratings. Model AK-1-15 is rated 15 to 225 amperes with a 15,000-ampres interrupting capacity while AK-1-25 is rated 35 to 600 amperes with 25,000-ampere interrupting capacity. Interchangeable dual magnetic trips have sealed-in, liquid-displacement time-delay devices using nonsludging silicone fluid. Arcing time is less than one cycle and silver-alloy contact tips eliminate deterioration due to oxidation and assure long tip life and low contact resistance. Breaker can be supplied for individual mounting or integral mounting with other switchgear. It is available for electrical or manual operation. Manufacturer: Switchgear division, General Electric Co., Schenectady 5, N.Y.

For further information circle MD 43 on Page 245

High-Output Temperature Pickup

Designed for a temperature range of minus 65 C to plus 150 C, the temperature transducer will produce a high voltage signal for small changes in temperature. The one-inch diameter unit consists of a sensitive bimetallic element which rotates a Microtorque potentiometer. The potentiometer, in



turn, produces large changes in voltage across its leads. Suitable for use with oscillographs, recording galvanometers and telemetering systems, the type 4911 transducer has an accuracy of one per cent and a sensitivity of one degree C or less; potentiometer resistances are available from 100 to 20,000 ohms. Manufacturer: G. M. Giannini & Co., Inc., 285 W. Colorado St., Pasadena 1, Calif.

For further information circle MD 44 on Page 245

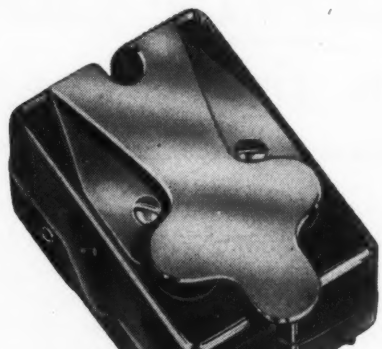
Transparent Protective Coating

Surfaces of all types of metallic and nonmetallic materials can be protected by Permacote, a new transparent liquid. The material can be applied by brush, spray or dip and forms a tough, flexible protective coating that will withstand acid, alkalies, alcohol, dyes and dirt. It is said to be resistant to extremes of temperature, and will not crack or chip owing to expansion of the surface. Manufacturer: State Chemical Corp., 1265 Broadway, New York 1.

For further information circle MD 45 on Page 245

Double Snap-Action Switch

Comprising an assembly of two standard Unimax switches mounted on an adapter plate, the type SA-1 switch provides for simultaneous actuation of both switches by the operating force. Either double-pole double-throw or double-pole single-throw assemblies are available; rating is 15 amperes at 125 volts or 5 amperes at 250 volts a-c. Assembly measures



1 15/16-inches long, $1\frac{3}{8}$-inches wide and 15/16-inch high. Overall length over adapter plate is $2\frac{1}{8}$ inches. Manufacturer: Unimax Switch Corp., 460 W. 34th St., New York 1.

For further information circle MD 46 on Page 245

Variable-Pitch Pulleys

Variable-pitch pulleys require no special control apparatus, being entirely controlled by the motor-mount adjustment. They are so designed that the

Now... Every drawing has this future!

IN SECONDS, you can reproduce *any* drawing as *any* one of a variety of Ozalid prints.

You simply select the desired type of Ozalid sensitized material . . . place your drawing on it . . . and feed into the Ozalid machine.

Thus, every drawing has a future which you control. A future which allows you to always match the print to the job at hand . . . and realize these definite advantages in drafting room, shop or office.

1. WILL COLOR CODING HELP?

Your drawings can be reproduced with black, blue, red or sepia lines on a white or tinted background. Thus, you can color code prints of different departments or operations—speed routing, reduce possibility of error.

2. PREFER PRINTS ON LIGHT, STANDARD, OR HEAVY WEIGHT PAPER?

You can make all three types with Ozalid . . . to suit your specific requirements. Light or standard weight prints for ordinary use or convenience in filing; heavy weight prints for reference charts, manuals, etc. You can even make Ozaprints with reproductions on both sides of the sheet.

3. ARE EXTRA MASTERS NEEDED?

You can make translucent Ozalid Intermediates directly from your tracings . . . and use these as Masters in your printmaking. This eliminates wear and tear on the original . . . also provides Masters for different departments, branches, subcontractors, etc. Ozalid Intermediates are actually better to print from than original drawings—for they increase line densities and can be made on new plastic-coated surfaces . . . impervious to staining and smudging.

4. WILL CHANGES OR ADDITIONS BE MADE TO ORIGINAL?

Valuable drafting time is saved with Ozalid. Instead of altering your original . . . you can make your changes or additions on a translucent Ozalid print. New products—like Ozalid Strip Film—with a transparent adhesive base—can be used to transfer title blocks or sections from one drawing or translucent Master to another.

5. WANT TO COMBINE ONE DRAWING WITH ANOTHER?

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6. WANT TO ELIMINATE PRINT REPLACEMENT?

If grease and grime are a problem in the shop or field, make your work prints on durable Ozaplastic, which can be cleaned in seconds with a damp cloth.

ALL OZALID PRINTS PRODUCED IN SAME MANNER

★ **No tie-ups when you shift from one type of print production to another. Simply choose your Ozalid material . . . and your Ozalid Streamliner exposes and dry develops it. Standard work prints are produced in 25 seconds.**

★ **Your drawings can be up to 42 inches wide, any length. Roll stock or cut sheets can be used. (Special machines accommodate 54" wide drawings.)**

★ **You—or anyone else—can be the operator. A few hours and you're an "expert."**

★ **See *all* the Ozalid prints you make from any drawing . . . and learn full story. Mail coupon today.**

DEPT. NO. 109

OZALID A Division of General Aniline & Film Corp., Johnson City, New York

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Name________ Position________

Company________

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Ozalid in Canada—Hughes Owens Co., Ltd., Montreal

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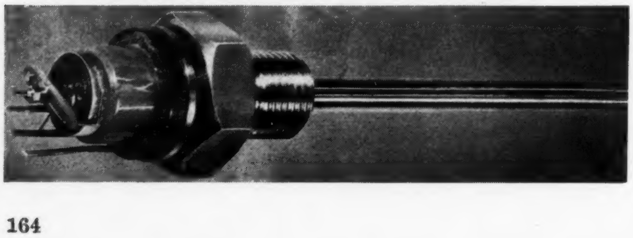

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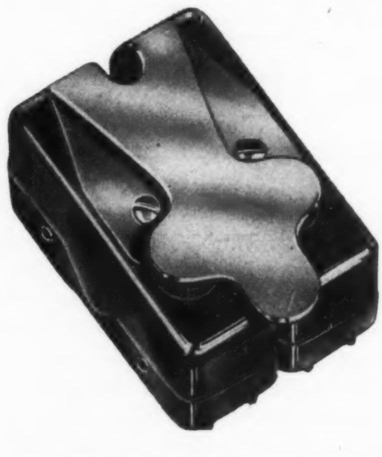

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ALL OZALID PRINTS PRODUCED IN SAME MANNER

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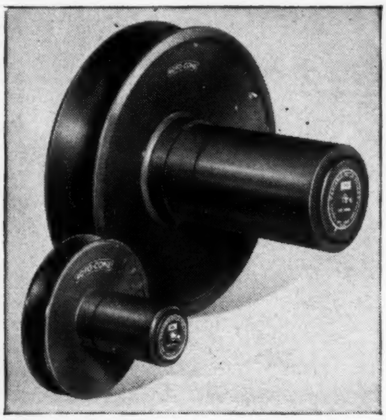
Name__________ Position__________

Company__________

Address__________

Ozalid in Canada—Hughes Owens Co., Ltd., Montreal

change in belt tension resulting from turning the motor-base adjusting handwheel changes the distance between the pulley disks and therefore changes the effective pulley diameter. A variable-speed ratio of 3:1 is possible with these Roto-Cone Pulleys and



horsepower ratings from 1/8 to 7½ are available to operate in conjunction with driven sheaves in the diameter range 3½ to 26 inches. Manufacturer: Gerbing Mfg. Corp., 154 E. Erie St., Chicago.

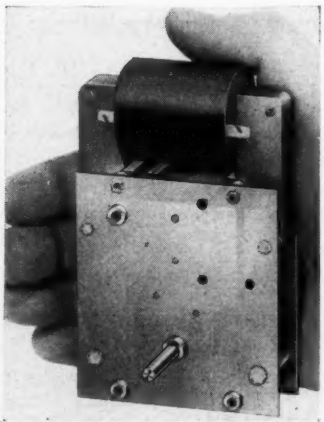
For further information circle MD 47 on Page 245

Protective Coating

Organic coating suitable for application by spray, dip or roller coating is said to give 20 year protection against corrosion. Air drying, these coatings, known as Zincilate, are flexible so that metal sheets can be bent double after the application without cracking the coating. Overcoatings of enamel or paint may be applied over the Zincilate after five minutes of air drying and both coatings baked at the same time. Typical applications include automotive assemblies, valves, piping, etc. Manufacturer: Industrial Metal Protectives Inc., Dayton 2, Ohio.

For further information circle MD 48 on Page 245

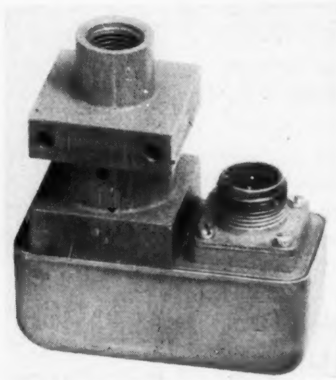
Fractional-Horsepower Motor



High torque capacity fractional-hp motor for operation on 115-volt 60-cycle current is rated 75 oz-in. torque. Of the shaded-pole induction type, the motor is small enough to fit the hand and is particularly suitable for use on such apparatus as coin machines, directional antennas and other equipment. The motor is constructed of aluminum and has a built-in gear train giving an output shaft speed of 20 rpm at no load. Mounting studs tapped with No. 4-36 thread, facilitate mounting. Particular feature of the motor is the magnetic clutch. Upon de-energizing the motor, the clutch disengages, preventing overtravel of the output shaft. Manufacturer: T. C. Smith Mfg. Co., 920 Washington St., Springfield, Ill.

For further information circle MD 49 on Page 245

Hydraulic Pressure Switches



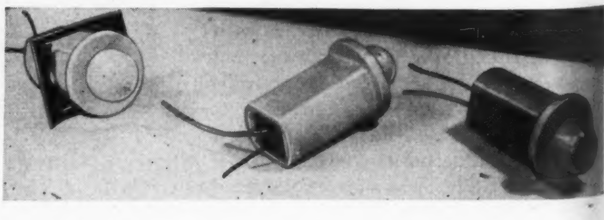
Designed to make or break an electrical circuit in accordance with preset pressures, the No. 9048 line of pressure switches can be made to operate throughout the pressure range 100 to 5000 psi. Recommended applications include automatic operation of sequencing valves and automatic control of fluid pumps and hydraulically controlled systems of all kinds. Units will operate on oil, gas or air and maintain a constant setting over the temperature range minus 50 F to plus 150 F. They measure 4⅜ by 3 3/16 by 1½ inches. Manufacturer: Saval Co., 1915 E. 51st St., Los Angeles 11.

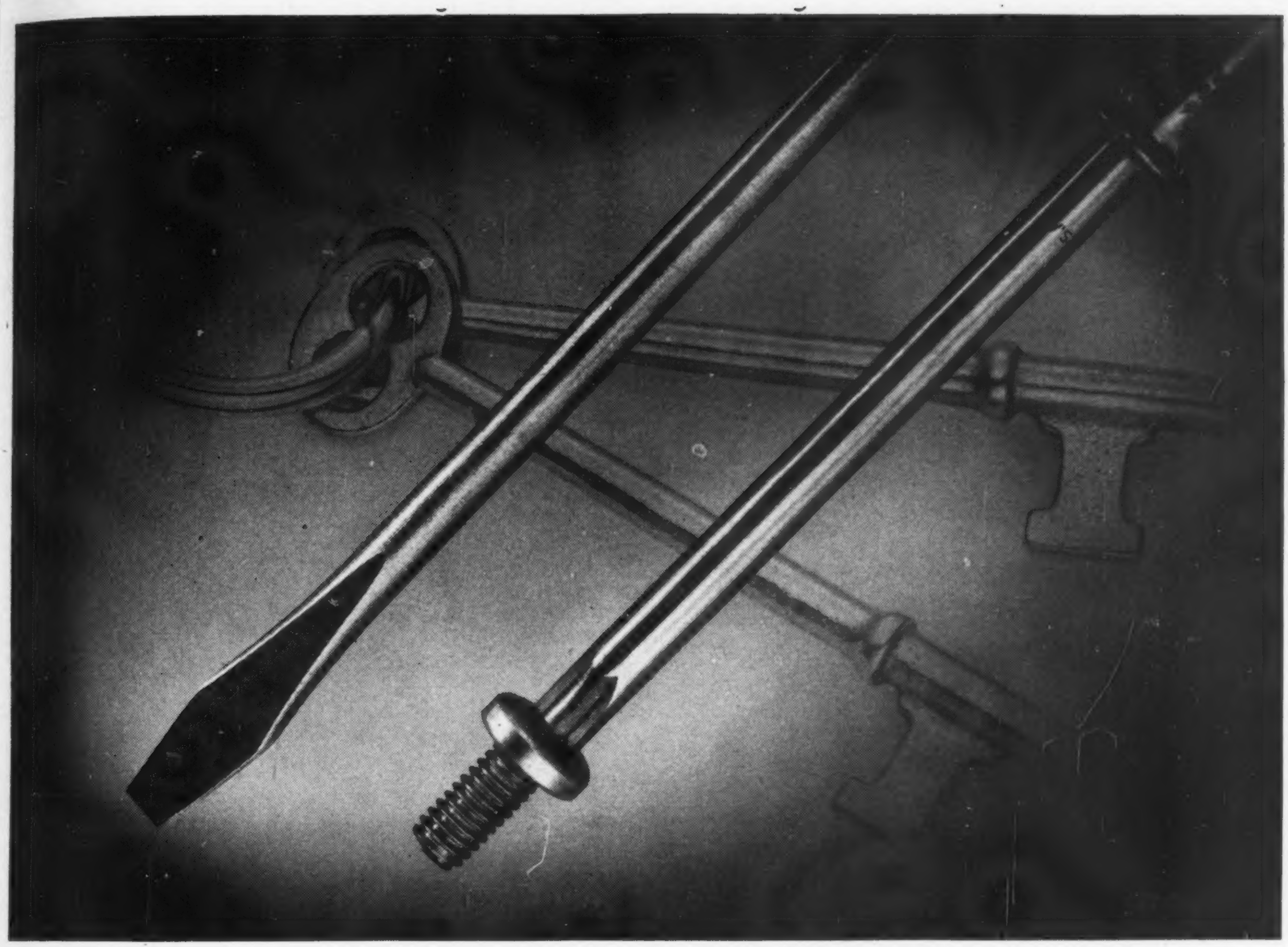
For further information circle MD 50 on Page 245

Indicator-Light Assembly

Small indicator-light assembly incorporates a standard NE-2 neon glow lamp and a resistor in one unit. Measuring 1 1/16 inches in length the lamp has a 7/16-inch diameter bull's eye, which is integral with the plastic housing of the assembly. Light transmitted through the plastic is said to be unobtrusive but effective. Installation is facilitated by the incorporation of a small decorative shoulder around the bull's eye. This allows the assembly to be inserted through a panel and secured on the far side by means of a locking clip. Units are available in a wide range of colors and choices of lead wire arrangements. Manufacturer: The American Electronics Corp., 226 N. 4th St., Columbus 15.

For further information circle MD 51 on Page 245





Here's How CLUTCH HEAD *Opens The Door To Simplified Field Service*

PERFORMANCE ON THE JOB measures the value of your product to the user . . . it also measures your reputation and your sales volume of the future. Hence, these two keys to simplified field service . . . *provided only by CLUTCH HEAD* . . . are vitally important to the quality and continuity of your job's performance.

KEY NO. 1 is the logical basic design of the CLUTCH HEAD recess for operation with a common screwdriver. Note that any flat blade will do and that it need only be reasonably accurate *in width* . . . that the roominess of the recess makes thickness of the blade a secondary consideration.

KEY NO. 2 is the Type "A" Hand Driver . . . the same rugged bit used for power driving on high speed assembly lines. This tool gives service men the benefit of the CLUTCH HEAD Lock-On, the reverse withdrawal action securely locking the screw to the end of the bit . . . holding it undamaged and saved for re-use. The same Lock-On feature operates in replacing the screws, permitting of easy one-handed reaching and frequently saving disassembling of surrounding units.

Likewise, in assembly power driving, CLUTCH HEAD Screws offer advantages unmatched by any other screw on the market . . . Center Pivot entry for automatic straight driving to avoid burred or chewed-up heads; the safety of non-tapered engagement to eliminate fatiguing end pressure and skid hazard; easier, faster driving for production increases ranging from 15% to 50%; the Lock-On to oust "fumbling fingers"; tool economy of a rugged bit that has driven up to 214,000 screws non-stop and that may be repeatedly reconditioned on the spot in 60 seconds. Check these exclusive features of America's Most Modern Screw by sending for screw assortment, sample Type "A" Bit, and illustrated Brochure.

CLUTCH HEAD SCREWS

UNITED SCREW AND BOLT CORPORATION

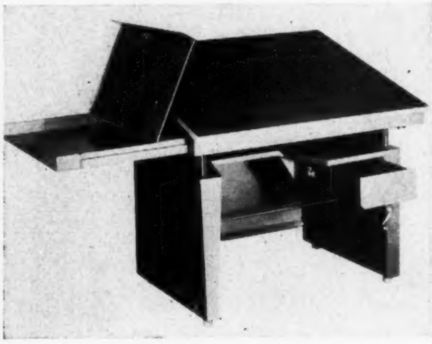
CLEVELAND 2 — CHICAGO 8 — NEW YORK 7

engineering dept equipment

In order to obtain additional information on this new equipment see Page 245

All-Steel Drafting Desk

All-steel Work Flow drafting desks are made in several sizes, providing drawing surfaces up to 60 inches in length. Tilt-top feature makes possible working angle up to 20 degrees. Height is adjustable from

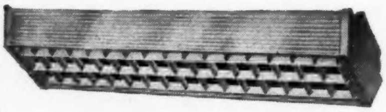


29¾ to 38 inches. Units are finished in metallic gray and have tops of linoleum. Manufacturer: Dept. MD, Haskell Mfg. Co., 206 Penn Ave., Pittsburgh 21.

For further information circle MD 52 on Page 245

Fluorescent Fixture

New fluorescent fixture for ceiling mounting has glass side panels to provide maximum illumination. Unit, known as the Illinois, has louvres that may be hinged from either side and mounting tracks which



lock fixture in place and prevent any shifting. Installation of glass panels can be made from the bottom of fixture, expediting maintenance. Four 40-watt lamps are used. Maunfacturer: Shenley Eelectric Products Co., 3540 Southport Ave., Chicago 13.

For further information circle MD 53 on Page 245

Force-Measuring Instrument

Instrument known as the "Dynamometer" has been developed for measuring forces in limited spaces. Measuring 3-inches in diameter and weighing one pound, the instrument is made in 100, 250 and 500-lb capacities. It has a Lucite crystal and red "maximum" hand while the dial is black with etched nu-

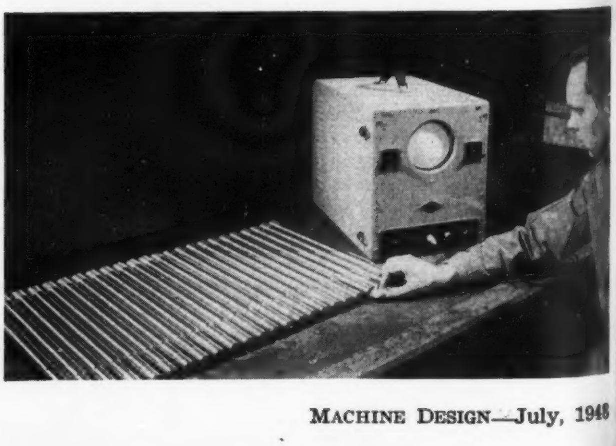
merals. Components are zinc die castings. Manufacturer: W. C. Dillon & Co. Inc., 5410 W. Harrison St., Chicago 44.

For further information circle MD 54 on Page 245

Supersonic Reflectoscope

Type SRO5 supersonic Reflectoscope can be used for nondestructive testing of metallic and nonmetallic materials for internal defects. Similar in general specifications to previous model, new unit has greatly decreased weight and bulk; measuring 14 by 16 by 23 inches it weighs 85 pounds. It is carried by handles on the case in contrast to wheeled carriage used on the former instrument. Sensitivity remains the same, operation, however, has been simplified by reduction of the number of controls to five. With these the operator can vary sensitivity, pulse width, sweep, length, screen markers, and frequency. Visual indication is upon a 5-inch high-intensity oscilloscope tube. Manufacturer: Sperry Products Inc., 1505 Willow Ave., Hoboken, N. J.

For further information circle MD 55 on Page 245



Machine Tools...

assembled with

AMERICAN PHILLIPS MACHINE SCREWS...

Cost Less to Make—

and to Use

THE BUILDER SAVES . . . because straight-driving, easy-handling American Phillips Screws cut assembly time as much as 50%. What's more, these modern, *engineered* screws banish burrs, outlaw scarred work-surfaces—and give a precision machine the final outward mark of inward quality.

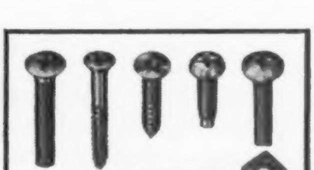
. . . AND THE BUYER SAVES, TOO . . . because every screw has been turned up flush, to utmost tightness . . . thereby minimizing vibration, and all the other headaches that follow when you get "a screw loose." And there are no burred heads to snag clothes, slash hands, cause accidents, lose time. Couldn't *you* use these advantages *and savings,* in your own product? Write.

AMERICAN SCREW COMPANY, PROVIDENCE 1, RHODE ISLAND

Chicago 11: 589 E. Illinois St. *Detroit 2: 502 Stephenson Building*

4-WINGED DRIVER CAN'T SLIP OUT OF PHILLIPS TAPERED RECESS

AMERICAN PHILLIPS *Screws*



ALL TYPES

ALL METALS: Steel, Brass, Bronze, Stainless Steel, Aluminum, Monel, Everdur (silicon bronze)

Assets to a Bookcase

Corrosion Handbook

Edited by Herbert H. Uhlig, associate professor of metallurgy, Massachusetts Institute of Technology; published by John Wiley & Sons Inc., New York; 1221 *pages,* 5¾ *by* 9 *inches, clothbound; available through* MACHINE DESIGN, $12.00 *postpaid.*

Said to be the first comprehensive treatment on corrosion ever published, this book brings together all pertinent information now available, much of which has never before been printed. Over one-hundred contributors and nine editors have discussed the subject, dividing it into eight general categories. These are: Corrosion theory, corrosion in liquids, special cases of corrosion, high-temperature corrosion, corrosion protection, testing, and corrosion-resistant materials to be used with high temperatures or chemicals. Being essentially a reference book, the volume has much of its information presented in easily consulted, headed form and is replete with tables, charts and illustrations.

□ □ □

Industrial Management

By William R. Spriegel and Richard H. Lansburgh; published by John Wiley & Sons Inc., New York; 656 *pages,* 5¾ *by* 9 *inches, clothbound; available through* MACHINE DESIGN, $5.00 *postpaid.*

This book, the fourth edition of the authoritative volume by the late Richard H. Lansburgh, has been revised and brought up to date by Professor Spriegel. In so doing the excellent balance between theory and practice, notable in previous editions, has been well maintained. This book is an excellent presentation covering organizational structure, wages, equipment, personnel administration and other pertinent subjects. As a reference and text on the general subject of management, this volume is strongly recommended.

□ □ □

Fluid Mechanics

By George F. Wislicenus; published by McGraw-Hill Book Co., New York; 613 *pages,* 5½ *by* 8 *inches, clothbound; available through* MACHINE DESIGN, $7.50 *postpaid.*

Covering hydraulic transmissions and couplings as well as turbines, centrifugal pumps and compressors, this book on fluid mechanics presents a rigorous analysis of the theory together with carefully developed design formulas. Starting with an introduction to the fluid mechanics of turbomachinery, the reader is acquainted with similarity relationships and such problems as turbulence and cavitation. Thence, he is introduced to theory of flow in hydrodynamic machines and the mechanics of the flow of compressible fluids. In conclusion, the reader is acquainted with the design of turbomachinery. While the author is, by his own admission, biased in the direction of pumps and compressors, he has produced a volume which is balanced and should be of value to many engineers concerned with fluid dynamics.

□ □ □

Steel and Its Heat Treatment

By D. K. Bullens and the metallurgical staff, Battelle Memorial Institute; published by John Wiley & Sons Inc., New York, in two volumes; Volume I, Principles, 489 *pages,* 5¾ *by* 9 *inches, clothbound; Volume II, Tools, Processes and Control,* 293 *pages,* 5¾ *by* 9 *inches, clothbound; available through* MACHINE DESIGN *postpaid, Volume I,* $6.00, *Volume II,* $4.00.

Presenting the practical as well as the theoretical side of heat treatment, this two-volume book will be of considerable value to all design engineers. It will serve as a guide in choosing the correct design materials, and provide an insight into the mechanics of heat treating as affected by design. This is the fifth edition of this well-known authoritative text, the previous edition having been published ten years ago. In the interim much war-gained information has been accumulated and added to these books. Subjects covered include: Terminology, testing, heat treating both pearlitic and austenitic steels, control of surface conditions, heating and cooling and heat treatment of ferrous castings.

Recently made available, the book "Shot Peening" is devoted to the theory, application and advantages of the shot peening process. Carefully prepared, the book is replete with data on peening. It gives, for example, comparison figures on the life tests of bars which have been given various surface treatments. The 181-page, 6 by 9-inch paper bound book is available at $1.50 from the American Wheelabrator & Equipment Corp., Mishawaka, Ind.

Noteworthy Patents

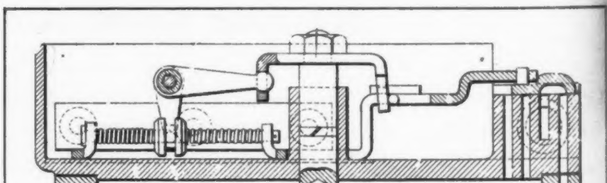
COMPOSITE-METAL rotor for high-speed applications, such as in gas turbines and superchargers, provides considerably superior service life. Assigned to General Electric Co. by Alan Howard, patent 2,432,-315 details the composite-metal rotor. Rim of the rotor which carries the buckets is formed of an alloy having good high-temperature properties. The web and hub portion, on the other hand, is formed from a material with good low-temperature properties and the two units welded into a single piece to provide a rotor capable of withstanding service conditions.

COMPLETE ELIMINATION OF SPRINGS, end rings, and other moving parts usually employed for actuating the floating vane members of rotary vane pumps is achieved by a simplified design covered in patent 2,423,639. Assigned to Eddington Metal Specialty Co., by Walter Czarnecki, this pump mechanism obviates need for the devices usually required to supplement centrifugal force in maintaining vane engagement with the pump body bore. Slots in the forward face of the vanes communicating with another along the inner edge of the vanes break the seal between the faces of the rotor slots and vanes and bring fluid under pressure beneath the inner edge to force the vane outwardly into contact.

SPOT WELDING of low-resistance metals such as brass, normally an impractical operation owing to difficulty in raising the metals to welding temperature in reasonable time, is readily accomplished by an unusual method covered in patent 2,432,631. To provide a rapid and practical means for preparing low-resistance parts for welding, a strip of high-resistance metal is placed over the part and slugs are punched from it into the low-resistance metal so as to remain partly protruding. By allowing the slugs to protrude, spacing of the low-resistance parts is automatically provided and concentration of the welding current takes place in the slug. Rapid fusion of the metal adjacent to the slug results. Patent assigned to Western Electric Co. by R. W. Rosendale.

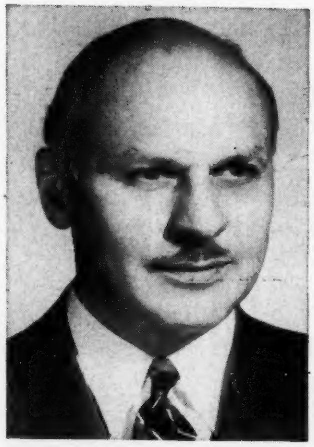
RAPID FILLING and emptying of a fluid coupling for accurately controlling the loading and unloading of such a coupling or clutch is provided by an automatic control valve arrangement outlined under patent 2,432,191. Assigned to Wright Aeronautical Corp. by Roland Chilton, the valving arrangement eliminates the delay normally encountered in unloading a fluid coupling by cutting off the supply of fluid. Bleed ports in the periphery of the coupling are automatically closed on application of fluid flow to the coupling but when pressure to the unit is cut off, spring pressure on the valve plate automatically opens the bleed ports to immediately cut off the transmission of torque. When operating full, fluid pressure balances the spring load on the valve to permit a continuous circulation of fluid through the coupling.

AUTOMATIC valve action for reversing the application of pressure to opposite sides of a piston is obtained by means of a crosshead actuator attached directly to the piston rod of a fuel pump unit covered in patent 2,433,759. Adaptable to either pressure or vacuum operation, the valve provides efficient and uniformly timed operation. Movement of the piston



in either direction actuates, by means of the crosshead, a bell crank which stores spring energy during the stroke to shift the slide valve when released by the crosshead lock. Pump displacement can be varied by changing the crosshead to effect the desired piston stroke. Patent assigned to Trico Products Corp. by Willis C. Hess.

MEN... of machines



Russell J. Nadherny

Walter L. Schneider

RUSSELL J. NADHERNY has been elected executive vice president and director of engineering and production of Barnes & Reinecke, Inc., Chicago. His previous position with this industrial designing and engineering organization was as chief engineer. Mr. Nadherny graduated from Cornell University in mechanical engineering in 1922 and was first associated with the steel and oil industries. However, his activities for the past fifteen years have been largely devoted to the design and development of production machinery and he has introduced many innovations in connection with material handling equipment which are well known in the industrial field. Mr. Nadherny was appointed chief engineer of the Mercury Mfg. Co. in 1936 and in 1943 was elected vice president in charge of engineering of Athey Products Corp. He is a member of the American Society of Mechanical Engineers and the American Society for Metals.

WALTER L. SCHNEIDER, for the past year vice president of the American Gear Manufacturers Association, and for many years active in its affairs, was elected the association's president during the recent annual meeting at Hot Springs, Va. Mr. Schneider is vice president of the Falk Corp. His entire career has been with that organization which he joined in 1925 shortly after graduating from Marquette University.

FRANK B. POWERS, long identified with the transportation industry, has been elected assistant vice president, engineering, of the Baldwin Locomotive Works, Philadelphia. Mr. Powers joined the Baldwin organization in January, 1947, as assistant to vice president, operations, and in July of that year he was given complete responsibility for all engineering activities of its Eddystone division. A graduate of the University of Illinois, 1926, Mr. Powers became associated with the Westinghouse Electric Corp., and in 1935 was appointed section engineer in charge of d-c traction motor design. He served as manager of transportation engineering from 1936 to 1938 and during the following six years was engineering manager of the corporation's transportation division. In the latter capacity he was responsible for design of steam turbine generators, hydro generators, rectifiers, ignitrons, large a-c synchronous and induction motors, steel mill motors, large marine motors, induction regulators and all transportation apparatus. Prior to joining the Baldwin company he was executive vice president of Great American Industries.

Frank B. Powers

ARNOLD F. MEYER JR., associated with the Heil Co., Milwau-

kee, since 1932, recently was appointed vice president in charge of engineering. Mr. Meyer is a mechanical engineering graduate of the University of Wisconsin and for two years following graduation was employed by the Hevi Duty Electric Co. During his association with the Heil company, Mr. Meyer has served as laboratory technician and welding engineer, a designer in the engineering department, assistant chief engineer and since 1943, chief engineer.

♦

ROBERT E. HARTSOCK recently has been named chief engineer of the Earthmaster division, Adel Precision Products Corp., Hollydale, Calif.

♦

FRED E. WEICK, designer and developer of the Ercoupe, has been appointed distinguished professor and research engineer for Texas A & M College. Mr. Weick will direct the personal aircraft research center which is being established in the college's department of aeronautical engineering.

♦

FRED E. FRICKE, formerly general works engineer for Fruehauf Trailer Co., Detroit, has joined Kraft Foods Co., Chicago, as chief engineer.

♦

C. F. DRUMM SR. is now general engineer of the Mack Mfg. Corp. engineering department. He previously was contact engineer between the organization's service engineering department at Long Island, N. Y., and its engineering department at Allentown, Pa.

♦

LAWRENCE R. ROTHERT has been named director of machine tool engineering for Kent-Owens Machine Co., Toledo, O.

♦

J. A. EDINBORGH recently joined the staff of the Foundation for Industrial Research at the University of Wichita as a research engineer to specialize in electronics and electrical engineering. Mr. Edinborgh comes to the foundation from the Naval Research Laboratory, Washington.

♦

PAUL M. KEYES has been appointed an instructor in the department of mechanical engineering, College of Engineering, University of Iowa. In addition to his teaching duties, Mr. Keyes will work with various Iowa industries in the fields of time and motion studies, industrial engineering and production methods.

♦

GEORGE G. SOMMARIPA has joined the staff of the American Standards Association as head of the national standardization work on consumer goods. Committees are now working on standards for home electrical appliances, household refrigerators, farm and home freezers.

♦

L. C. HOSFIELD has been appointed head of the machine development department at the Edgewater works of National Carbon Co., Cleveland. He succeeds P. DRUMMOND who has recently become associated with the Pratt & Whitney Div., Niles-Bement-Pond Co.

♦

DR. A. V. ASTIN, assistant chief of the electronics division of the National Bureau of Standards, has been awarded His Majesty's Medal for Service in the Cause of Freedom by the British government for his work during the war on the use and evaluation of the radio proximity fuse.

♦

D. W. R. MORGAN, general manager of the Steam, Aviation Gas Turbine, and Stoker divisions of the Westinghouse Electric Corp., has been elevated to vice president. He continues, however, to direct operations of the three divisions mentioned. A mechanical engineering graduate of Ohio Northern University and associated with Westinghouse since 1913, Mr. Morgan has served as manager of the Steam division condenser engineering department and as assistant engineering manager of the division.

♦

J. B. SCHLIEMANN has been named acting chief of design operations of the Chance Vought Aircraft Div., United Aircraft Corp.

♦

A. C. DENAPOLI, associated with the sound recording and business equipment industry since 1927, has been appointed chief engineer, The Sound-Scriber Corp., New Haven, Conn.

♦

KEITH F. GALLIMORE, vice president in charge of engineering, Giddings & Lewis Machine Tool Co., Fond du Lac, Wis., recently was elected to the company's board of directors.

♦

JOSEPH H. SCHAEFFER, engineer in charge of the Bolt and Nut Machinery division, Waterbury Farrel Foundry & Machine Co., Waterbury, Conn., has been promoted to vice president as has F. S. VAN VALKENBURG, engineer in charge of the company's Eyelet and Wire Drawing Machinery division.

♦

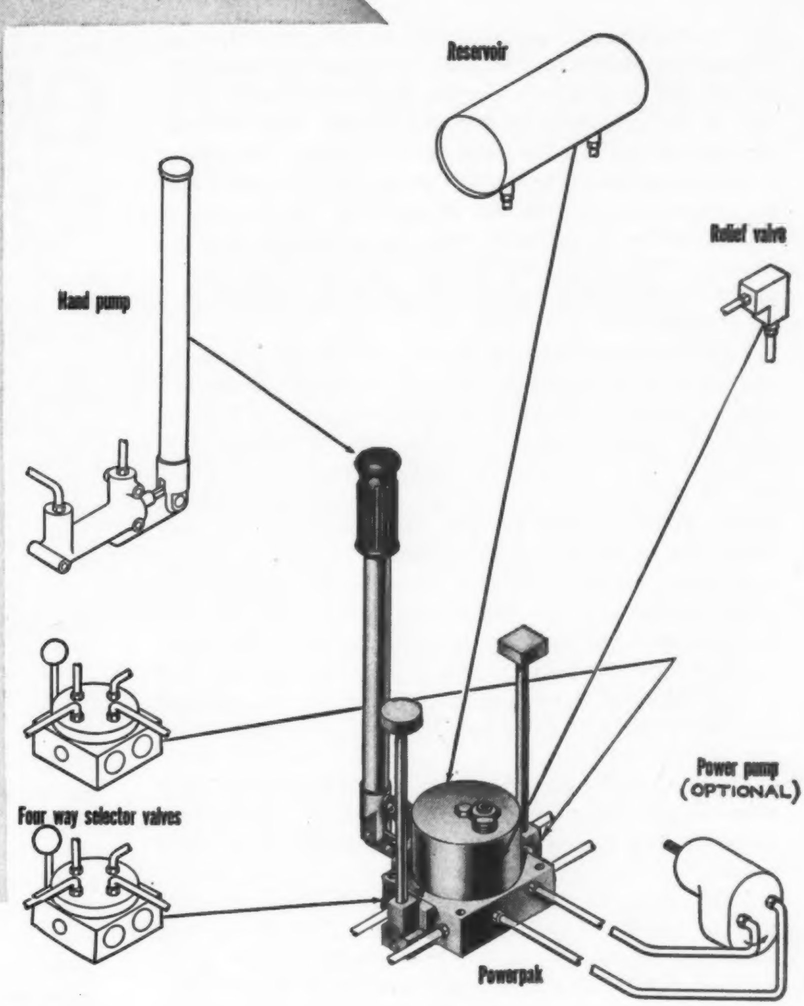
A. M. MACCUTCHEON, who retired in 1946 from the position of vice president in charge of engineering of the Reliance Electric & Engineering Co., Cleveland, has been presented the 1947 Lamme medal of the American Institute of Electrical Engineers at the institute's summer general meeting. Mr. MacCutcheon was so honored "for his distinguished accomplishments in the development of motors for industrial needs, notably in the steel industry."

♦

JOHN D. COCHRANE JR., director of research and development for the Formica Insulation Co., Cincinnati, has been presented the John Wesley Hyatt award for his outstanding work in the development and improvement of decorative laminates. Mr. Cochrane is seventh recipient of the award which is named in honor of Hyatt who developed the first thermoplastic, celluloid, in 1867.

"Nerve Center" OF TODAY'S HYDRAULIC SYSTEMS...

The ELECTROL POWERPAK



At work, as the hydraulic-system control center in a wide variety of machines in industry, transportation and agriculture, the Electrol Powerpak has well earned its title as "the little giant of industry."

Compact in design, with a base measuring but 3½" x 4", the Powerpak is capable of exerting precision-controlled forces by fingertip actuation—from 0 to a maximum operating pressure of 1,500 p.s.i. It can be conveniently positioned from the operator's standpoint, with only the pump handle and selector valve levers projecting into the open. Also, the standard, straight pump handle can be curved or shortened to meet any specific requirement.

Another advantage of the Powerpak is its adaptability. A power-driven pump, for example, can be utilized simply by removing two plugs to connect pump pressure and suction lines to the unit. Or the reservoir capacity—12 cubic inches on the model illustrated — can be increased as individual requirements necessitate.

Electrol's long-experienced engineering staff will gladly work with you in adapting the Powerpak to the machines you use or the products you make.

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VALVES • CUT-OUT VALVES • SPEED CONTROL VALVES

FOR BETTER HYDRAULIC DEVICES

Trapped Stresses

(*Concluded from Page* 118)

ing circumferential compression, at the same time as it is drawn down in an axial direction with tension. At the rim of the cup tension and compression combine to a high shear stress and plastic flow without cracks results. In the case of the flange, the stress is tensile around the circumference of the hole, and no compressive stress can be applied. Consequently the operation is difficult even for relatively shallow flanges. Bridgman has shown that even marble is plastic under conditions of simultaneous tension and compression.[2]

The compressive trapped stress produced by methods such as shotpeening or heat treatment acts in a similar fashion to prevent brittle failure. This is shown by *Fig.* 6, taken from the Mattson and Almen National Defense report.[3] The figure shows the test life of three types of springs. Production springs, drawn to Rockwell C-52 and shotpeened, gave an average life of about 160,000 cycles. Springs tested as quenched, without drawing or peening, lasted only about 20,000 cycles. They were too brittle, but the brittleness could be offset by shotpeening. The same springs, quenched to Rockwell C-62, not drawn, but peened, showed the remarkable life of almost 400,000 cycles for the poorer of two and about 700,000 cycles for the better of two.

Similar results have been obtained with parts which were brittle when cold. After peening, the impact value at low temperatures was increased to normal values.

This phase of the use of trapped stresses—their use to reduce brittleness—has been explored less than other applications, but it seems likely that great savings can be obtained when it is more fully understood how higher hardness, with corresponding higher yield strength, can be used without sacrifice in ductility and fatigue life of finished parts.

Practical Methods

PRODUCTION OF TRAPPED STRESSES: The useful effects of trapped compressive stresses would be of little interest if there were no practical means of producing such stresses. Fortunately there are many ways in which such stresses can be trapped so that the designer and manufacturer usually has a choice of methods.

Cold Work: One group of methods relies on cold deformation. They produce work hardening and small changes in surface besides the trapped stresses. Theoretically the simplest of these methods is overstressing. The autofrettage of guns is one example of overstressing. Overspeeding of turbine disks and presetting of springs are others. The fundamental principle in all overstressing operations is to produce a cold deformation by load applied in the same direction as the future service load. It is therefore suited to parts which in service are stressed in one direction only.

Shotpeening is the most universal method of producing trapped stresses. It results in a compressively stressed skin, *Fig.* 7. This method has been developed from an almost accidental discovery some twenty years ago to a well controlled production process used for parts as diverse as cutting tools and crankshafts. Ability to hit fillets and similar areas of stress concentration is one outstanding merit of this method. To this may be added freedom from distortion and improvement of surface.

Burnishing by rollers works in a way quite similar to shotpeening, but is limited in application to round parts of fairly regular shape.

Controlled Cooling: Another group of methods relies on controlled cooling to produce trapped stresses. As all metals, and most other materials, shrink when cooling, and at the same time become less plastic, the areas which cool first will be under compressive stress while the areas which cool last will be subject to tensile stresses. In welding, the trapped cooling stresses are often unfavorable. In castings they can be arranged in a favorable pattern by skilled use of chills. Tempered glass is an outstanding commercial

Methods For Trapping Stresses

Mechanical	Thermal	Metallurgical
Overloading	Selective quenching	Carburizing
Burnishing	Shrink fitting	Nitriding
Shotpeening		Shallow hardening

example of the use of trapped stresses, produced by controlled cooling, to increase strength. The hot, plastic, sheet of glass is rapidly quenched on the surface. As the core cools more slowly it shrinks and pulls the surfaces together, leaving them in a state of compressive stress. The ability to resist loads and deflections is increased to several times its original value by this treatment. Shrink fits are a similar application of trapped stresses produced by different rates of cooling.

Metallurgical Methods: The last group of methods, apparently the most difficult and complicated, actually is one of the oldest. It relies on metallurgical phase change, which is accompanied by increase in volume, to produce compressive stresses in the surfaces of parts. Carburizing is one of these methods, shallow quenching another. In addition to producing high hardness, which can as well be obtained with through-hardening steel, these methods use the volumetric expansion which accompanies the martensite transformation to set up compressive trapped stresses. The magnitude of these stresses can be guessed by anybody who has seen the quench-cracks produced by the same forces when they are not properly controlled.

REFERENCES

1. O. J. Horger and C. H. Lipson—"Automotive Rear Axles and Means of Improving Their Fatigue Resistance," *Symposium on testing of parts and assemblies, Technical Publication No.* 72, American Society for Testing Materials, 1947.
2. P. W. Bridgman—"Effect of Hydrostatic Pressure on the Fracture of Brittle Substances," *Journal of Applied Physics,* Vol. 18, No. 2, Feb., 1947, Page 246.
3. R. L. Mattson and J. O. Almen—*Report on the Effect of Shotblasting on the Mechanical Properties of Steel* (3 volumes), War Metallurgy Division of the National Defense Research Committee of the OSRD (available as photostats or microfilm).

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Alert engineers will tell you that all mechanisms, machines or products in which there are bolted assemblies will loosen soon, unless you use spring washers.

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DESIGN ABSTRACTS

Standardization of Steel Mill Crane Components

WHEN the dimensions of rolled steel sheave wheels were investigated by the crane committee of the Association of Iron and Steel Engineers, it was found that these wheels seemed to have been individually designed for each crane. As a result there were hundreds of designs. In many cases the grooving was not correct for the size of cable to be used and a pinching action on the cable resulted. By working with the Wire Rope Association, the best radius for the bottom of the groove and the slope of the sides were determined. The next step was to work with the wheel manufacturers on the general contour design so that the proposed wheels could be manufactured, and finally to determine the sizes to be used. It was agreed that wire rope sizes for mill cranes started at ½ inch and increased by ⅛ inch sizes up to 1¼ inches. On this basis 10 sheave wheels were listed, the pitch diameters of which were 30 times the diameter of the rope. In the 1, 1⅛ and 1¼-inch sizes, two diameters of wheels are required. For these cranes an additional sheave wheel was adopted for each size of rope, making a total of 13 standard wheels.

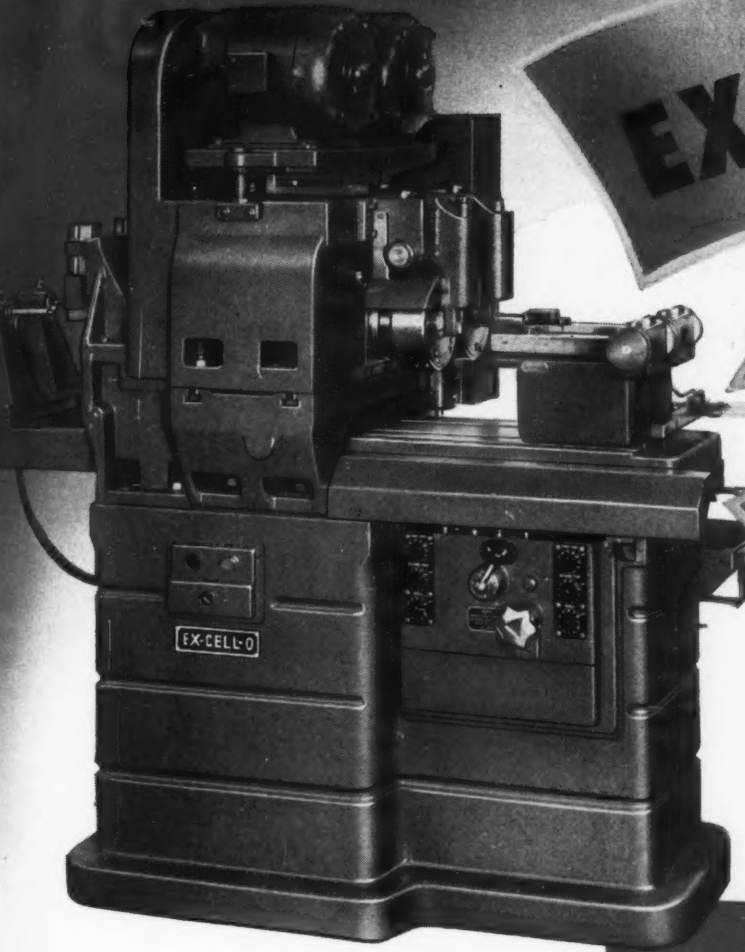
Number of Track Wheels Greatly Reduced

Crane track wheels were a more difficult problem. Data were collected from several plants on the sizes and dimensions of wheels used on the mill type cranes. The original listing contained about 700 different wheels. To have crane track wheels available for the range of conditions involved and capable of having good life with wheel loads ranging from 25,000 to 140,000 pounds, it was necessary to list 28 wheels as standards. In addition to these, there are many existing cranes where end truck design will not permit the standard wheels to be used. To fill this need, four additional straight tread wheels and six tapered wheels were added to the list for use with existing cranes only.

Four Coupling Blanks Sufficient

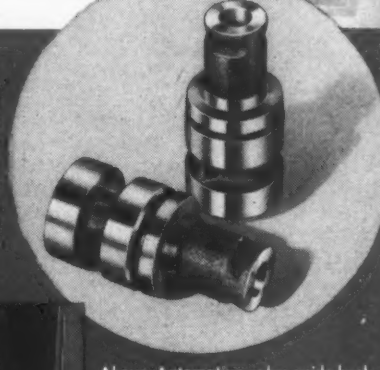
Another item investigated was the solid couplings for shafting. After a thorough analysis of this subject, it was found that four sizes of rolled steel blanks would be required to make couplings suitable for shafting from 2½ inches to 6 inches in diameter. The hubs are of sufficient thickness to accommodate the standard key way for the largest shaft. The adopted keys are standard sizes.

Perhaps the most interesting of the standardization subjects on the AISE program is that of the mill type motor. The standard main dimensions of these motors are one of the outstanding achievements

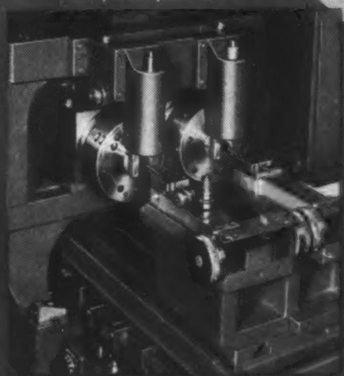


EX-CELL-O CAN GIVE YOU MORE ECONOMICAL PRODUCTION

Above: Full view of Ex-Cell-O Style 2112-A Precision Boring Machine arranged for automatic rough and finish boring of valve guide bushings. Parts enter chutes at left end of spindles, are fed through hollow spindle shafts to chucks, are rough and finish bored and ejected, all automatically, at the rate of *300 pieces per hour.*



Above: Automotive valve guide bushings with 11/32" holes, 2-3/16" long that are rough and finish bored on the machine shown above left.



Left: Close-up view of spindles and boring bar supports. Vertical castings in front of chucks house locating plungers that, when lowered, limit the forward travel of the bushings. Locators are withdrawn during boring and ejecting portions of cycle. Graduated dials on boring bar supports permit accurate adjustment of boring bar to control size of hole.

THIS ENTIRELY AUTOMATIC PRECISION BORING MACHINE IS TYPICAL OF EX-CELL-O SUPERIORITY IN ENGINEERING

● Here's a machine that receives automotive valve guide bushings from a conveyor line, rough and finish bores them and delivers them to another conveyor, all automatically. The bushings, 2-3/16" long with 11/32" bores, enter chutes at the left end of the spindles, are fed through the hollow spindle shafts to the chucks, are located, clamped, rough and finish bored and ejected at the rate of *300 pieces per hour.* Bores are held to a tolerance of .001". The operator need never touch the parts except to inspect the bores occasionally.

The engineering know-how that makes possible an automatic machine such as this one is always available to Ex-Cell-O customers, whether their work requires parts in short runs or great volume. Whether tolerances are measured in thousandths or ten-thousandths, Ex-Cell-O engineers will suggest the most practical and efficient method of finishing your parts. Call Ex-Cell-O today!

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of the Association. There are eleven standard frame sizes listed for these motors, which can be obtained with series, compound or shunt windings. They will be made by three manufacturers and be interchangeable not only in physical dimensions but for horsepower, torque and speed. They are also interchangeable with the existing frame sizes, but the horsepower and speed rating of the next higher frame will be built into the new motor.—*From a paper by F. W. Cramer, engineering division, Carnegie-Illinois Steel Corp., presented at a Chicago district meeting of the Association of Iron and Steel Engineers.*

Design of Rocket Motors

A ROCKET engine of the liquid propellant type consists of a thrust cylinder, an injector and a propellant valve. A great deal of money can be spent by a newcomer into the rocket field on a complicated type of injector. The propellant they may imagine must be spun, swirled, atomized or mixed by striking the side wall. However, the simple jet impingement type injector is found to be most suitable for whatever propellants may be used.

Supply of propellants to a thrust cylinder must be controlled by valves, which are usually designed so that they are normally closed. In case of electric power or pressure failure the valves close. This is of importance in test operation. In test, two sets of valves or more in series may be used so that anywhere along the propellant feed lines the propellants can be stopped and in some cases water introduced into the lines to dilute the propellants that may flow out after shutting down.

Valve Design Affected by Size

A common type of propellant valve is one that has a piston and yoke operating two pintles. These pintles are accurately contoured to give the correct mixture ratio during starting. Another type is a solenoid-operated spring-loaded cylindrical piston with a special sharp-edged seat. For 5000-lb thrust rocket engines and up, piston type valves similar to the familiar intake and exhaust valves used on aircraft engines may be used. For large rocket engines of 100,000-lb thrust, frangible disks may be used.

One other item connected with a rocket engine is the starting system. If the thrust cylinder fills with propellants before combustion can take place, a hard start may result. A typical starting system for a bi-propellant system has two small propellant valves opening for ignition. The flow from these valves is enough to produce 50 to 100 psi chamber pressure, which opens the main propellant valve for the coolant. As the coolant flows into the injector its presence opens up the other main propellant valve and both main propellants flow through the injector simultaneously. The timing of the propellants entering the injector and thrust chamber can be varied as may be found necessary.—*From a paper by Alfred K. Huse, Reaction Motors, Inc., presented at the recent SAE National Aeronautic and Air Transport meeting in New York City.*

Engineering Department

(*Concluded from Page* 128)

specifications for production, cannot be overemphasized.

AIDS TO PERFORMANCE: A file on patents that may be important to the company is vital to the proper functioning of an engineering department. It must make sure that the product it designs does not infringe upon the patents of others. It should also bring to management's attention new patents that may have a bearing upon the company's products.

It should be the responsibility of the engineering department to keep abreast of technological developments; and for this purpose, it should maintain an up-to-date library of new books bearing upon subjects in which it is interested, and of important magazines.

In order to function properly the department must maintain a sound plan of numbering drawings and parts and keeping all records of drawings, material lists, and specifications. It must also maintain a workable system whereby changes on drawings are recorded and issued.

Organization Manual Is Necessary

For the organization to function effectively, it is imperative that a manual be issued, setting forth the functions of each individual heading up the various departments. The duties of each person should be specifically spelled out in this manual; including the duties of the head of the department with relationship to the department which he heads and with relationship to the rest of the executive organization. Only on the basis of specific definition of duties can an engineering department be operated in such a way as to eliminate confusion and mistakes.

PROGRESS: Years ago, it was common for an executive of a company to step out into the shop and say, "I need something to turn out so-and-so. Let's have your ideas." Whereupon somebody in the plant would try to design something. He did not care how long it took to build it. Neither did he care about the material costs involved.

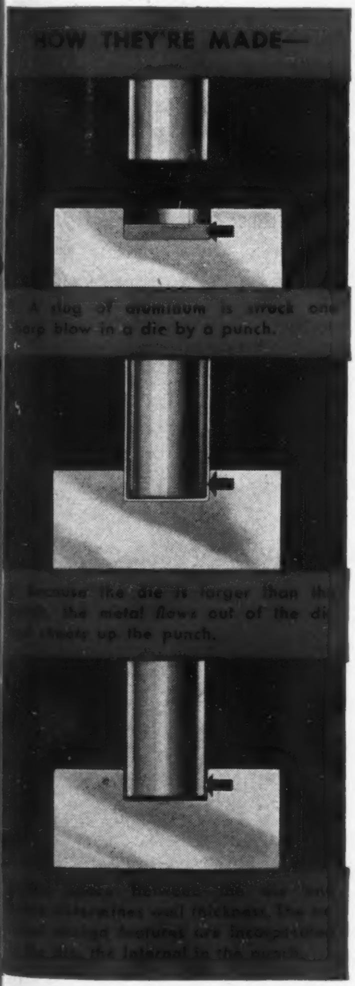
That was all right in those days, because when we were first getting into our pace in this country, as far as production efficiency was concerned practically every new machine devised was better than anything we had ever had before. But those days are over.

Today, engineering is not merely a matter of ingenuity with respect to performance of the product designed. It is a matter of ingenuity with respect also to manufacturing costs, to the selection of materials, to the quantities required, to the quality demanded, to the preferences of the customer, to accounting procedure and tax laws, and a host of other factors of which the inventive shop mechanic of twenty-five years ago never even dreamed.

The only answer to modern-day problems is *organization*. That is, organization which properly dovetails the engineering department into the functioning of the company as a whole.

THE NEW THERMOS* IS A KNOCKOUT

because Alcoa Aluminum takes a Wallop



The shell of the new all-aluminum *Thermos** brand vacuum bottle is an Alcoa Aluminum Impact Extrusion, formed in one mighty wallop from the aluminum alloy biscuit shown above at far left.

By using an Alcoa Aluminum Impact Extrusion, American Thermos Bottle Company gives the new *Thermos* brand bottle these sales advantages . . . higher strength than a stamped or drawn shell, lower unit cost for the shell, lighter weight for the finished bottle, gleaming beauty that will never be marred by rust.

Almost any shape that is symmetrical can be made as an Alcoa Aluminum Impact Extrusion. Bosses, vertical fins, lugs, and other special features are formed integrally at the moment of impact. Few tools are required, and these cost little. Parts costs are less, almost no finish machining is necessary, design possibilities are unlimited.

Let us show you the variety of parts made as Alcoa Aluminum Impact Extrusions. Your designer's imagination will find places to use impact extrusions in your products.

ALUMINUM COMPANY OF AMERICA, 1940 Gulf Building, Pittsburgh 19, Pennsylvania. Sales offices in 54 leading cities.

*Trade mark of American Thermos Bottle Co.

ALCOA FIRST IN **ALUMINUM**

1888 ALCOA ALUMINUM 1948

60 YEARS OF SERVICE

Gyroscopes

(*Continued from Page 105*)

tion and rate gyroscopes have been combined in one system. But most applications employ either one or the other.

Bombsight Gyro: The small gyroscope of *Fig.* 5 is approximately the same size as the toy gyro-top, but it has ten times the angular momentum. Its total weight is only ten ounces but an angular velocity of one radian per second causes it to develop a torque of 0.75 pound-inches. This gyroscope is designed for a bombsight where minimum size and weight are important. Its umbrella-type, hysteresis-driven rotor runs at a synchronous speed of 12,000 rpm on a three-phase, 400-cycle power supply. It can be used either in a rate or position-controlled system.

Antiroll Gyro: At the other extreme in practical designs are large gyroscopes for stabilizing ocean liners and large yachts. The eleven-foot-diameter rotor of a large gyro whose total weight is 100 tons is shown in *Fig.* 6. This unit stabilizes a 5000-ton yacht by limiting its roll to only a few degrees even in a rough sea. The rotor is driven at 930 rpm by a 275-hp, 3-phase, squirrel-cage motor mounted directly on the shaft. At this speed its angular momentum is approximately 5,000,000 pound-feet-seconds. During stabilization, where the maximum precessional velocity may be 0.5 radians per second, the gyroscope will supply a stabilizing torque of 2,500,000 pound-feet.

Antihunting Control in Servo-Systems: Use of a gyroscope for antihunting control in servo-systems is one of the most interesting applications. First described by C. R. Hanna of Westinghouse Research Laboratories, it has been employed in electric drives for tank turrets and radar-tracking antennas.

Stiffness Important

In a position-controlled servo-system, the stiffness (the torque developed at the output per unit angular error) must be kept high if high position accuracy is required. If the servo-system has several large time delays, it is difficult to obtain high stiffness along with a sufficient amount of system damping and therefore some form of antihunt device is generally needed.

Antihunt is obtained by introducing a rate or velocity response in a position-controlled system and resistance-capacity circuits are often used for this purpose. In these circuits the current through the resistance is proportional to angular deviation and current through the capacitance is proportional to its rate of change. Such a circuit is effectively employed where electronic amplifiers are to be used.

If electronic amplifiers are not available, a small gyroscope can be used to respond to angular velocity of the system and thus supply the desired rate response for antihunting. A schematic of the servomechanism used for the tracking system of an SCR-270 radar antenna is shown in *Fig.* 7. An angular

Let us send you FREE this new

Operates on the slide rule principle

FALK Coupling Selector

A few features of the new FALK Coupling Selector

1. Shows selection factor for most types of driven machines at a glance.
2. "Window" in slide gives instant reading for coupling size, maximum bore, maximum rpm—based on application requirements (selection factor, hp and rpm).
3. Complete Dimension Tables for Steelflex Couplings (sizes 3F to 18F) printed on back of Selector.
4. Simple, easy-to-follow instructions for using Selector clearly printed on front.
5. Selector is of handy pocket size, firmly made to withstand regular use over a long period.

. . . makes it easy to order the right coupling for any requirement! Ends guesswork—insures accuracy!

When you see the handy, new, slide-rule-type FALK Coupling Selector, you'll understand why men in industry everywhere hail it as "the most valuable little device that's come along in recent years"!

This Selector enables you to select, in a jiffy, exactly the right FALK Steelflex Coupling for practically **any** need, without having to consult a book or look up reference tables. You just set the Slide so that the required horsepower is directly over the desired speed (r.p.m.), and you are shown the correct coupling size based on selection factor (application) and maximum bore. It's amazingly simple . . . fast . . . accurate . . . reliable!

We will gladly send you one (more, if needed) of these highly useful Coupling Selectors if you will fill out and mail the coupon below. We suggest that you do this at once to avoid possible delay.

FALK . . . a good name in industry!

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Precision manufacturers of Speed Reducers . . . Flexible Couplings . . . Motoreducers . . . Herringbone and Single Helical Gears . . . Heavy Gear Drives . . . Marine Turbine and Diesel Gear Drives and Clutches . . . Steel Castings . . . Contract Welding and Machine Work. District Offices, Representatives, or Distributors in Principal Cities.

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Milwaukee 8, Wisconsin

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movement θ_i of the input for tracking results in an angular displacement θ_o of the antenna. Any angular difference between the input and output synchros $(\theta_i - 72\theta_o)$ appears as an error θ_e at the differential synchro. The angle θ_e is applied to a small gyroscope spring-centered about its precession axis so that the entire assembly is deflected in proportion to θ_e. This deflection, θ_e, is added to the gyroscopic precession it causes, which is proportional to the rate of change of θ_e. The total deflection is applied to a Silverstat (a multiple-contact resistance assembly), whose output current is then a function of both error angle and rate of change of error angle.

Automatic Pilot: The assembly of three small rate gyroscopes shown in *Fig.* 8 (one is mounted in the rear) is part of the control for a new automatic pilot for airplanes. As it employs rate gyroscopes, the Autopilot, as it is known, retains control of the plane during rapid accelerations in any direction and during any maneuver, even the loop-the-loop and barrel roll. Because of this ability to retain control, the Autopilot, now in its test stage for conventional planes, may be applicable to guided missiles and pilotless aircraft. Other features are light weight, simplicity, a direct inbuilt means of banking control and a reduction in power requirements.

Commercial importance of the gyroscope today results from the impetus given it by the expansion of air transportation and the Second World War. Airborne gyroscopes were used during the war to solve numerous requirements unique to aircraft so that today there are few large airplanes that do not depend on their aid in navigation and automatic control. New uses, however, have added little to the basic gyroscopic principles, but rather, have led to refinements in mechanical and electrical design and to new servo-systems so essential for their practical application.

Among the more important future applications for the gyroscope will be the improved automatic control, the Autopilot, for piloted and pilotless aircraft. Future elevators may use the gyroscope to obtain accurate levelings at floors and railway coaches may be correctly banked when rounding turns to provide greater passenger comfort by means of a gyro-pendulum.

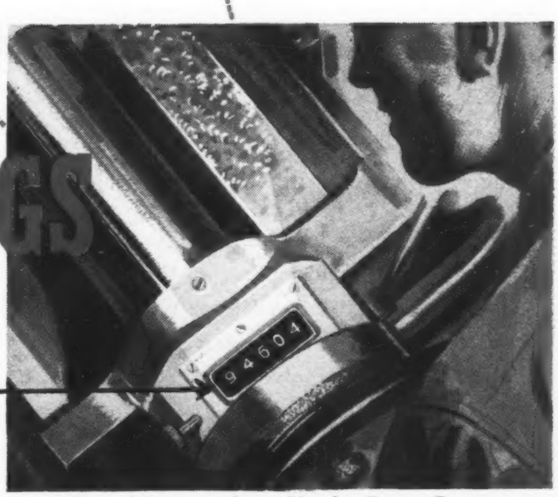
Spot-Welding Guns Standardized

SPOT-WELDING GUNS designed with and constructed from interchangeable standardized parts are now being produced by Progressive Welder Co. of Detroit. Seven basic gun types are used in heavy-duty and standard-duty versions to take care of 95 per cent of all gun welding requirements. These replace a multiplicity of gun designs each of which had been developed to meet the needs of specific jobs. Guns can be quickly converted to different jobs by changing one or two standardized parts. As many as 57,600 practical variations can be obtained with a single basic gun chassis by varying only the jaw extensions and standard electrodes.

HOW THESE DIRECT VEEDER-READINGS

Can Have DIRECT EFFECT

on your Product's Sales



EXAMPLE: Direct-reading Veeder-Root Counter on milling machine, replacing oldstyle dials with hairline graduations that strain eyes, invite errors. This counter controls depth of cut . . . is pre-set to indicate in ten-thousandths of an inch.

Tell your slow-poke prospects that your product now offers them an entirely *new usefulness* . . . through a built-in Veeder-Root Counter.

Tell them your product now keeps count of its own performance . . . in terms of strokes, revolutions, pieces, volumes, trips, or any other unit.

Tell them they get *direct* readings in bold, black and white figures . . . nothing to be converted or translated.

Tell them your product can now *prove* its service guarantee.

Tell them this . . . and *then* see how you sell them!

Veeder-Root makes all types of mechanical and electrical counters, readily adaptable as built-in parts of any type of machine or product. Find out how *you* can count your way to greater sales. Write to Veeder-Root Inc., Hartford 2, Conn.

Veeder-Root COUNTERS

MEETINGS AND EXPOSITIONS

Aug. 10-13—

First Western Packaging Exposition and Conference to be held in the San Francisco Civic Auditorium, San Francisco. Clapp & Poliak, Inc., Empire State Bldg., New York 1, are managing the exposition.

Aug. 18-20—

Society of Automotive Engineers. West Coast meeting to be held at the St. Francis Hotel, San Francisco. John A. C. Warner, 29 West 39th St., New York 18, is general manager.

Aug. 24-27—

American Institute of Electrical Engineers. General meeting to be held at Spokane, Wash. Additional information may be obtained from headquarters of the society at 33 West 39th St., New York 18, N. Y. H. H. Henline is secretary.

Aug. 26-Sept. 11—

Machine Tool and Engineering Exposition to be held at Olympia, London, England, under the sponsorship of the Machine Tool Trades Association of Great Britain.

Sept. 7-9—

American Society of Mechanical Engineers. Fall meeting to be held at Portland, Oregon. Additional information may be obtained from headquarters of the society at 29 West 39th St., New York 18. C. E. Davies is secretary.

Sept. 7-9—

Society of Automotive Engineers. Tractor and Diesel Engine meeting to be held at Hotel Schroeder, Milwaukee, Wisconsin. John A. C. Warner, 29 West 39th St., New York 18, is secretary and general manager.

Sept. 13-17—

Instrument Society of America. Third National Instrument Conference and Exhibit to be held at Convention Hall, Philadelphia, Pennsylvania. Richard Rimbach, 1117 Wolfendale Street, Pittsburgh 12, Pa., is exhibit manager.

Sept. 13-17—

American Society of Mechanical Engineers. Instruments and Regulators division meeting to be held at Philadelphia, Pa. Additional information may be obtained from headquarters of the society at 29 West 39th St., New York 18. C. E. Davies is secretary.

Sept. 13-18—

International Mechanical Engineering Congress to be held in Paris, France, sponsored by the Engineering Trades Associations of the principal industrial nations of Western Europe. Program will be directed toward new methods in metal working and manufacturing techniques. Following the congress the **French Machine Tool and Engineering Show** will be held in Basel, Switzerland, **Sept. 18-25.** Further information may be obtained from the Secretariat General du Congres International des Fabrications Mecaniques, 11, avenue Hoche, Paris (VIII^e) France.

Sept. 20-21—

American Society of Mechanical Engineers. Aviation division meeting to be held at Dayton, Ohio. Additional information may be obtained from headquarters of the society at 29 West 39th St., New York 18. C. E. Davies is secretary.

Sept. 20-24—

Illuminating Engineering Society. National technical conference to be held at Hotel Statler, Boston, Mass. Further information may be obtained from the headquarters of the Society, 51 Madison Avenue, New York 10, N. Y.

Sept. 27-Oct. 1—

Society of the Plastics Industry. Third National Plastics Exposition to be held at Grand Central Palace, New York City. Further information may be obtained from headquarters of the society at 295 Madison Avenue, New York. William T. Cruse is executive vice president.

What Every Designer Should Know *about the versatile Gear Shaper and its ability to cut costs in quantity production of all types of Contours.*

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BUSINESS AND SALES BRIEFS

CHARLES T. Button was recently appointed vice president in charge of sales of the Howell Electric Motors Co. At the same time, he was elected a director of the company, succeeding J. H. Hazelhurst. Concurrently, Thomas J. Manning, formerly assistant to the president, was named a vice president of the company.

♦

Three new appointments have been made to the sales organization of Telechron Inc. The first of the new appointees, Ernest J. Keefe, has joined the staff of the St. Louis sales office with headquarters in Kansas City, Mo. David D. Lash, has been appointed to the Philadelphia sales staff to cover the Baltimore area, while Harry J. Murphy Jr. has joined the Chicago sales office from which he will serve the Minneapolis territory.

♦

Offices and manufacturing facilities of the Martin-Quaid Co. have been moved to 1815 W. Sedgley Ave., Philadelphia. New location has increased manufacturing space, allowing the company to meet the demands of increased business.

♦

Previously associated with Trumbull Mfg. Co., L. C. Watson has been appointed sales manager of distributor sales for the Allen-Bradley Co. He will have his offices in Milwaukee.

♦

Four new appointments have been made in recently-organized divisions of General Electric company's apparatus department. New managers of the divisions include William C. Elcan of the ordnance sales division, Edward G. Haven of the aviation division, Earl K. Henley of the marine division and Royce A. Beekman of the federal and marine engineering divisions.

♦

Appointed vice president and general manager of the Rodic Rubber Corp., John H. White Jr. will direct

the production and sales of numerous standard and special rubber items.

♦

Walter Geist was elected to his seventh term as president of the Allis-Chalmers Mfg. Co. at the recent meeting of the company's board of directors. Several appointments in the sales departments were made concurrently. These include John R. Queen who has been named dealer supervisor at New York for the Empire State region and William D. Nesbeitt who was made manager of the Spokane district office.

♦

Formerly manager of equipment sales, Maynard B. Terry has been appointed general sales manager of the American Brakeblok Div. of the American Brake Shoe Co. He will continue to be located at the division's headquarters in Detroit.

♦

With offices at 1255 South Flower St., Los Angeles, Joseph Pierson and Assoc. will represent Potter and Brumfield in the west. Operating from Los Angeles, San Francisco and Honolulu, the distributors will serve California, Nevada, Utah, Arizona, New Mexico, and Hawaii.

♦

According to a recent announcement, M. H. Courtenay has been appointed SKF district manager for the Atlanta office. In this post, Mr. Courtenay will supervise a territory covering Florida and Alabama as well as portion of Georgia, Tennessee, Mississippi and Louisiana.

♦

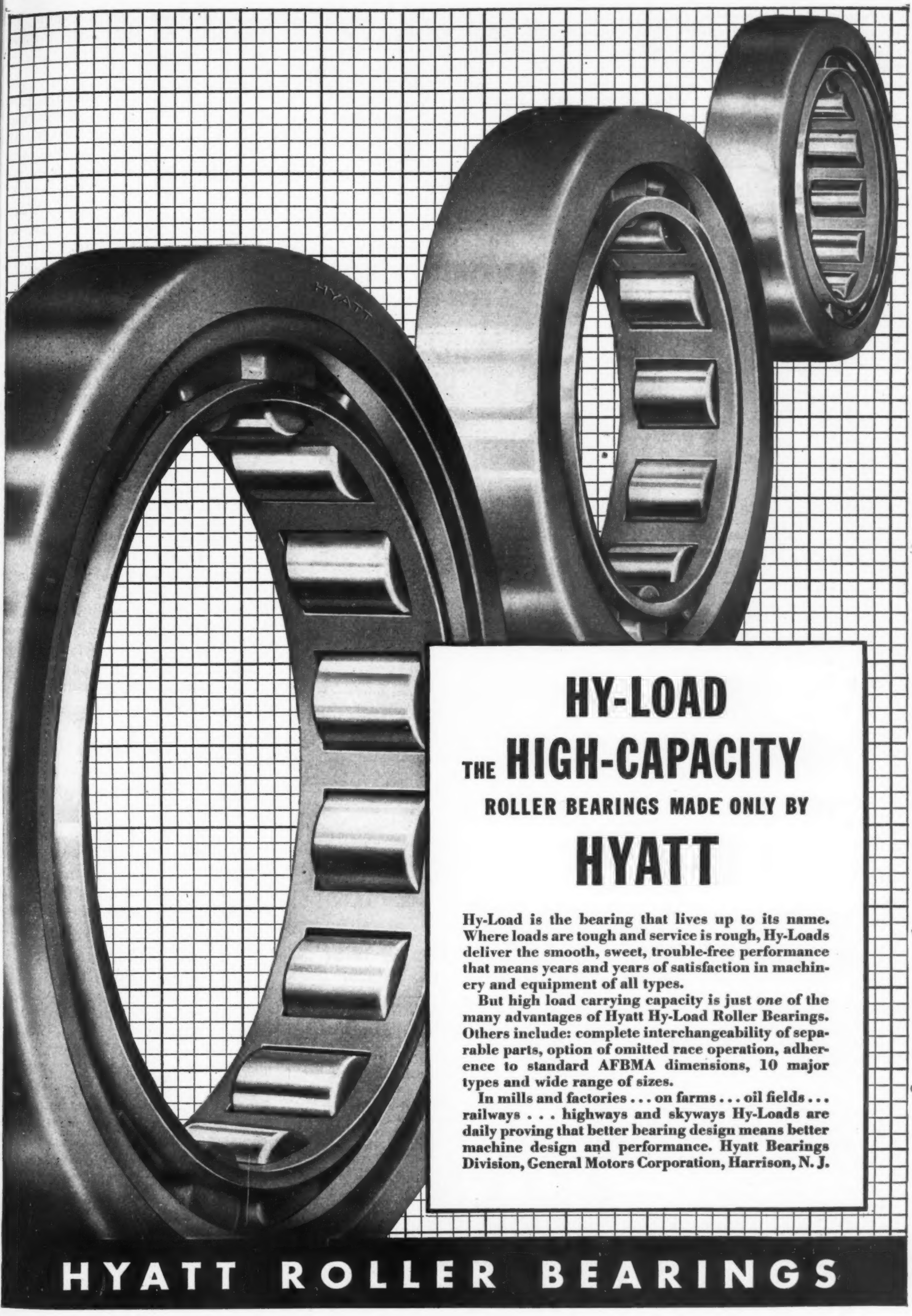
Named manager of heating control sales of the Penn Electric Switch Co., R. V. Clark will make his headquarters at the Goshen, Indiana, office of the company. Mr. Clark was formerly district manager of the company's Dayton office.

♦

Building and research expansion program to cost $30,000,000 has been planned by the DuPont Co. Said to be the largest single laboratory project the company has ever undertaken it will make Wilmington experimental station one of the largest research establishments in the world.

♦

Associated with the die-casting industry for over 30 years, George A. Meyer has been appointed vice president of the die-casting division of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ROLLER BEARINGS MADE ONLY BY
HYATT
Hy-Load is the bearing that lives up to its name. Where loads are tough and service is rough, Hy-Loads deliver the smooth, sweet, trouble-free performance that means years and years of satisfaction in machinery and equipment of all types.
But high load carrying capacity is just *one* of the many advantages of Hyatt Hy-Load Roller Bearings. Others include: complete interchangeability of separable parts, option of omitted race operation, adherence to standard AFBMA dimensions, 10 major types and wide range of sizes.
In mills and factories . . . on farms . . . oil fields . . . railways . . . highways and skyways Hy-Loads are daily proving that better bearing design means better machine design and performance. Hyatt Bearings Division, General Motors Corporation, Harrison, N. J.
HYATT ROLLER BEARINGS

Art Metal Corp. He will have his offices at New Hyde Park, New York.

♦

Headed by J. C. Wilson Jr., a new group has recently acquired the Acro Welder Co. Mr. Wilson, who was formerly executive vice-president and director of Burlington Mills Inc., was elected president. Other officers are L. R. Matthews, vice president; W. C. Messinger, secretary; J. C. Wilson Sr., treasurer; and T. B. Wilson, assistant secretary-treasurer.

♦

Board of directors of Kurz-Kasch Inc. re-elected the following officers at its annual meeting: J. J. Bauman, president; W. G. Davidson, treasurer; and R. F. Young, secretary. Mr. Davidson was also elected vice president to take the place of Mr. Kasch who died recently.

♦

Acquisition of a 215,000 square-foot warehouse has been made by Warner Electric Corp. to facilitate the handling of orders.

♦

Edward M. Griffith was recently appointed vice president of the Jessop Steel Co. Mr. Griffith has been in the steel business 45 years, having been president of the Defiance Pressed Steel Co. as well as executive vice president of the Cuyahoga Steel and Wire Co.

♦

Capital stock of the Anker-Holth Mfg. Co. has been purchased entirely by Jay Creswell, president of Pneumatics Inc.

♦

Brown Instrument Co. has initiated a $2,500,000 program to increase its manufacturing space more than 60 per cent. Program includes construction of a four-story addition to its Philadelphia plant.

♦

Opening of a new sales office in Chicago and the appointment of a new distributor in Grand Rapids, Mich., have been announced by Economy pumps. Beldon S. Tucker, formerly with the Institute of Inter-American Affairs, has been appointed district sales manager of the Chicago office with facilities at 105 W. Monroe St. New distributor for western Michigan is Bruce Hetler, who has been active in the pump industry for 25 years.

♦

According to a recent announcement, W. F. Sewert has been appointed manager of hardware prod-

ucts for the Wickwire Spencer Steel Div. of the Colorado Fuel and Iron Corp. His office will continue to be at 500 Fifth Ave., New York.

♦

Election of Forrest E. Richmond as vice president of Revere Copper and Brass Inc. and executive head of that company's Rome division was announced recently. Succeeding Mr. Richmond as works manager of the Rome division is L. G. Glesmann.

♦

New York Belting and Packing Co. has announced the appointment of Ray Caldwell as representative of the company's northeast district embracing New England, metropolitan New York, northern New Jersey and eastern Pennsylvania. His headquarters will be in New York.

♦

Retaining his position as manager of distributor sales for the Morse Chain Co., D. C. McNeely has been named manager of the Morse-Rockford Sales Div. The newly organized division will market a line of small-diameter over-center friction clutches.

♦

Wolverine Tube Div. of Calumet & Hecla Consolidated Copper Co. is constructing a new tube mill in Decatur, Alabama. The plant, occupying 260 acres on the shores of the Tennessee river, will manufacture seamless nonferrous tube by the electrodeposition process and will employ 350 people.

♦

Appointed eastern division manager for the Geo. D. Roper corporation's pump division, Robert L. Moog will take charge of the New York office at 55 W. 42nd St. In his new capacity he will supervise sales of Roper rotary pumps in New York, Connecticut, and New Jersey.

♦

With offices at 191 S. Main St., East Longmeadow, Mass., the Bay State Bronze and Aluminum Co. has been licensed by Ampco Metal Inc. to produce castings from Ampco metal ingot.

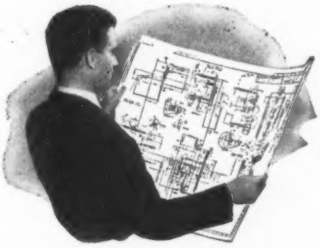
♦

According to a recent announcement, Lawrence A. Franks has been appointed manager of the Boston district office of the H. K. Porter Co. Inc. Mr. Franks, who was formerly a sales engineer with Bird and Sons Inc., will be located at 294 Washington St., Old South Bldg., Boston 9.

♦

New branch office has been opened in the west by General Controls Co.;

This new photographic paper gives you top-quality intermediates at low cost



It gives you everything—for intermediates and second originals—in *one* paper . . . With this one paper—Kodagraph Autopositive—you get everything you want. Here is a paper that gives you brilliant, black-on-white intermediates or second originals. A paper that gives sharp, clear reproductions of opaque drawings, faded originals, blueprints or direct process prints, weak-line "unprintable" pencil tracings. A paper that assures better-than-ever shop-prints. A paper that's tough, long-lasting, non-curling . . . that permits quick, easy deletions and changes.

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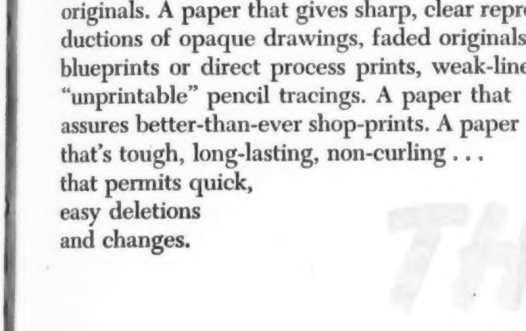

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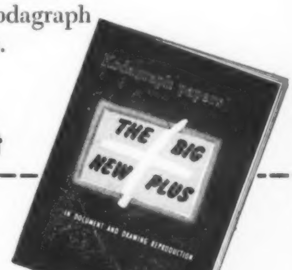
Specify . . . it will pay you . . . Your own reproduction department can make intermediates for you on Kodagraph Autopositive Paper. Or your local blueprint service will be glad to do the job and to make direct process prints or blueprints from the intermediates, if you wish. Be sure—though—to specify the new Kodagraph Autopositive Paper. Write for details.



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located at 1162 Elati St., Denver, the office is under the direction of M. S. Wilson.

♦

In Albany, N. Y., Link Belt Co. has opened a district sales office with J. Charles Bullock as district sales manager. Replacing the Schenectady office, it is located at 309-310 First Trust Co. Bldg., 444 Broadway, Albany 7.

♦

John O. Glenn, formerly assistant manager of the merchandising division, has been appointed manager of pump and compressor merchandising sales by Worthington Pump and Machinery Corp., Harrison, New Jersey.

♦

Appointment of Albert B. Willi Jr. as assistant chief engineer in charge of sales engineering has been announced by Federal-Mogul Corp.

♦

Federal Tool and Mfg. Co. has announced moving into their recently completed plant. Located at 3600 Alabama Ave., St. Louis Park, Minneapolis 16, the new plant has four times the floor space of their previous factory.

♦

Two appointments have recently been made in the sales department of the United States Rubber Co. In the main office, Harry W. Brown has been made sales manager succeeding S. E. Abramson, who has retired. Also, E. J. Briske has been appointed Detroit district manager for the company's automotive department.

♦

Covering the southern part of the United States, H. H. Jarrett and Assoc. now represents Atlas Chain and Mfg. Co. Territory includes North Carolina, South Carolina, Virginia, Georgia, Tennessee, Alabama, Mississippi, Arkansas, Florida and Louisiana.

♦

According to a recent announcement, Walter H. Flynn has joined the sales organization of the Lebanon Steel Foundry. Mr. Flynn, who was formerly with the Symington Gould Corp., will be located at the main sales office at Lebanon.

♦

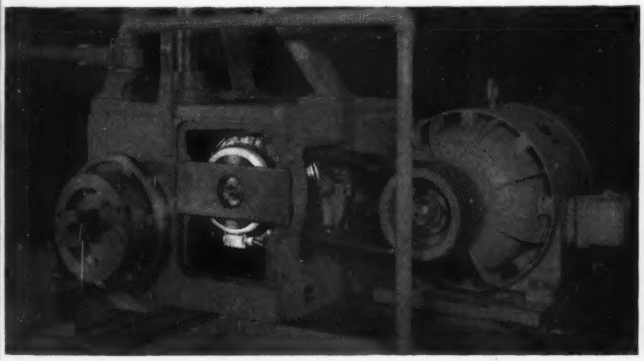
Alfred N. Lawrence has been appointed aviation division sales manager for Jack & Heintz Precision Industries. Mr. Lawrence has been with the organization for the past four years, coming there from United Aircraft Products Inc. where he served as sales manager.

HOW TO BETTER CONTROL AN AUTOMATIC LATHE

give it a Brake*!

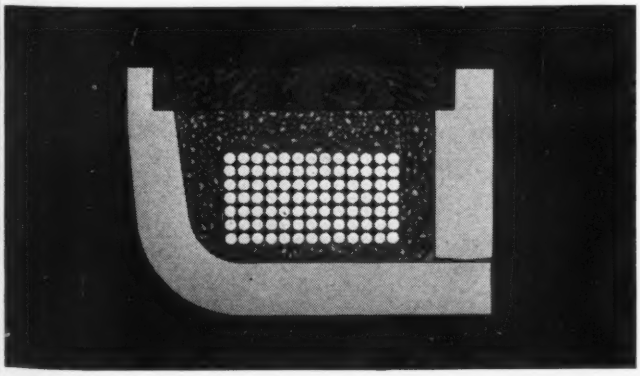
***And the Brake to give it is a WARNER ELECTRIC INDUSTRIAL CLUTCH-BRAKE**

SUNDSTRAND MACHINE TOOL CO. USES 3 Warner Electric Industrial "ICB" units on their Model 16 Automatic — Two on main spindle drive and one on rapid traverse. Here's what they say about them — "Easy to Control." Main drive motor is standard 75 hp. and constantly running. Warner ICB* units give positive instant control for starting and stopping of spindle. That means short cycle time . . . no special electrical equipment . . . no sudden power surges on factory lines.



HERE'S WARNER ICB UNITS installed on drive shaft of Sundstrand Model 16 Automatic. Sundstrand says these units are "compact, easy to install" . . . and most important "need no adjustment." ICB Units are available in wide range of sizes to meet requirements. Can also be fitted to standard NEMA motor shafts.

ARMATURE SECTION: One of only two parts for either Clutch or Brake units. Consists of magnetic segments welded to steel backplate (see cut). Especially designed for high heat dissipation. Heat has no effect on unit efficiency because segment expansion is always linear . . . thus keeping full magnet contact at all times.



MAGNET SECTION: The other of the two parts for either Clutch or Brake units. Consists of electro-magnet faced with long-wearing, high friction material. Power, applied through coils imbedded below (see cut), uses both friction *plus* magnetic attraction for fast, super-powerful clutch or brake action.

• Warner ICB Units* are low-cost key to more automatic, safer operation of wide variety of motors and machinery . . . give you infinite control of degree of clutch or brake action. For details or engineering assistance write: INDUSTRIAL DIVISION, WARNER ELECTRIC BRAKE MFG. CO., Beloit, Wis.

WARNER

ICB UNIT*

*ICB Unit — The trade designation for the Warner Electric INDUSTRIAL CLUTCH OR BRAKE UNIT.

NEW MACHINES

And the Companies Behind Them

Communication

RECORD AND TRANSCRIPTION PLAYER. Portable; dual-speed; two motors. Speed selection by positive-action lever; turntable rim driven. 7-watt push-pull amplification; three tubes, one rectifier; 8-in. permanent-magnet speaker; continuously variable tone control; crystal pick-up with replaceable osmium point. Operates on 105-115 volt a-c. Radio Corp. of America, RCA Victor Div., Camden, N. J.

Domestic

ELECTRIC FAN. One-piece construction plastic propeller. Chromium-plated base, motor housing and guard. Visual speed control; three speeds. Operates on 115-volt, 60-cycle a-c. Motor, shaded-pole induction type. Net weight, 19 lb. Fresh'nd-Aire Co., Chicago 1.

CHIME CLOCK. Hall type; electric. 70 inches high; two-tone mahogany case; dial two-tone brushed gold finish, silver numeral circle. Westminster chimes sound quarter hours. Operates on 60-cycle, 110-125 volt a-c. General Electric Co., Bridgeport 2, Conn.

UNIT BOILER. Five sizes, for 320, 400, 550, 700 and 900 sq ft of steam radiation. Fired by low-fuel-consumption oil burner; flame shape control. Light weight cast refractory brick combustion chamber. Water-level gage; built-in hot-water heater. Homease Products Co., Paterson 3, N. J.

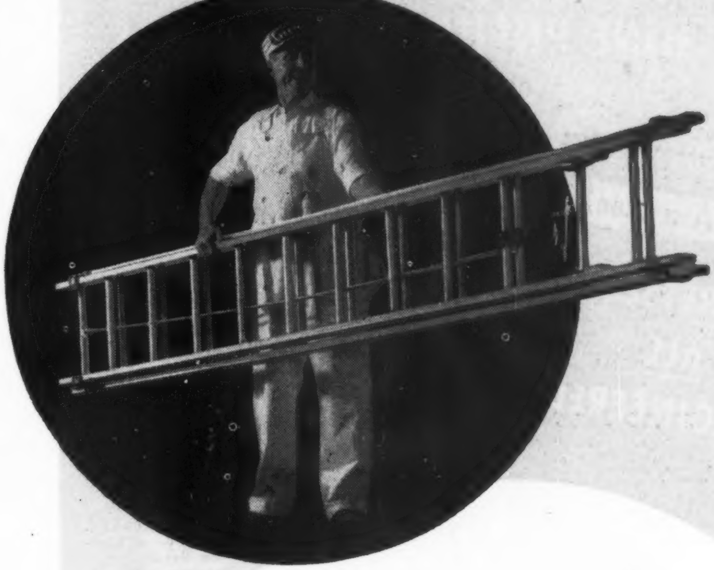
VACUUM CLEANER. Tank type. Disposable porous pressed-cotton bag installed inside cloth filter bag. Toe control switch; eight-foot reinforced hose; swivel nozzle; finished in gray; polished end caps; full-length glider rail. Weight, 15 lb. General Electric Co., Bridgeport 2, Conn.

ELECTRIC RANGE. Automatic. Lighted pushbutton controls. Oven heating unit sealed in walls; automatic reset oven timer; four surface units, one adjustable for deep-well cooker; warmer unit with pushbutton switch; finger-tip ball-bearing drawers with locked stop. Hotpoint Inc., Chicago 44.

Finishing

AUTOMATIC DIPPING MACHINE. For etching glassware, plating, dyeing, painting, etc. Parts are placed in metal basket which is dipped and agitated in tanks for cycled pe-

A REVEALING NEW BOOK—Here's the inside story on how manufacturers of a wide range of products have found that it pays to use magnesium. It's a book of actual case studies of successful magnesium applications—a book that will be of direct interest to you.



How Magnesium Pays

IN MANUALLY HANDLED EQUIPMENT

PROBLEM:
Reducing weight meant reducing handling costs of this ladder. That's why the manufacturer considered substituting another material for wood. He found wood unnecessarily heavy, and subject to warping, rotting and splintering.

SOLUTION: Magnesium extrusions are welded, riveted or bolted together to make a variety of sizes—ranging from stepladders to 24′, 32′ and 36′ extension ladders. Magnesium first provides lightness. The 24′ extension ladder in wood weighs 63 pounds—in magnesium only 28 pounds. Second, by eliminating rotting, warping and splintering, greater durability has been achieved in the magnesium type. Since the properties of magnesium are more uniform than those of wood, more efficiently designed sections can be used.

YOU, TOO CAN MAKE MAGNESIUM PAY!

Magnesium pays for others—it can pay for you. Get the facts—send for this new study today.

MAGNESIUM DIVISION, THE DOW CHEMICAL COMPANY, MIDLAND, MICHIGAN

Send me the study MP 49 "How Magnesium Pays." without obligation.

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Dow Chemical of Canada, Limited, Toronto, Canada

riods of time. Controls permit automatic, semiautomatic and manual cycling; emergency stop button provided. Farnham Mfg. Co., Buffalo, N. Y.

Foundry

CORE-BAKING MACHINE. Electronic. Capacity, 650 lb of cores per hour. Cores conveyor-fed through tunnel of machine. All heat generated within cores, no heat being given off to surrounding atmosphere. Length is 16 ft, 9 in.; width is 4 ft, 4 in.; height is 6 ft, 8 in. Induction Heating Corp., Brooklyn 11, N. Y.

Industrial

SEWAGE PUMP. Nonclogging. Radial and thrust bearings enclosed in cartridge. Six rings of lantern packing for external seal connection provided on stuffing box. External adjustment takes up wear at impeller inlet. Economy Pumps, Inc., Hamilton, O.

Laboratory

ELECTRIC KILN. Semimuffle type. Heats to 2700 F for normal operation, 3000 F for "flash" firings. Working chamber, 9 by 9 by 9 in. Deep-hinged, plug type heat-seal door. Safety pilot light; circuit breaker cut-off switch; indicating pyrometer and automatic temperature controller. Pereny Equipment Co., Columbus 8, O.

Maintenance

FLOOR MACHINES. For cleaning and polishing floors. Electric. Handle controls. Removable handles are adjustable in length and angle. Five models; brush spreads from 12 to 20 inches. Breuer Electric Mfg. Co., Chicago 40.

Manufacturing

ARBOR PRESS. Pneumatic. For forming, flaring, stamping, crimping, riveting, etc. Operates on line pressures from 5 to 175 psi. Built-in speed-control valve. Stroke length adjustable to 2½-in. max. Table size, 8 by 9 in. Throat clearance, 5 in. The Bellows Co., Akron, O.

POWER SCREW DRIVER. Will also serve as nut setter. Air powered; reversible; balanced. Drives No. 1 to 10 machine and wood screws, ¼-in. nuts. Working speed, 750 rpm. Reverse mechanism button controlled; adjustable friction clutch. Weight, 2¾-lb; length, 9⅛-in. The Aro Equipment Corp., Bryan, O.

HAMMER-AND-FEEDER UNIT. For staking, forming, pressing, and assembling small parts. Mounts on bench. Pneumatic. Rotary feed table indexing synchronized with hammer blows. Cycles to 5000 per hour. Base, 12 by 17 inches. Mead Spe-

cialties Co., Chicago 41.

METAL STITCHER. Solenoid controlled, adjustable for single-cycle or continuous operation. For stitching steel, aluminum, etc. Clincher, 45 in. above floor. Powered by ½-hp motor, 1725 rpm, V-belt drive. Weight, 585 lb. Bostitch, Inc., Westerly, R. I.

BANDSAW. For precision, high-speed cutting of metals, wood, plastics, etc. Four-wheel type; deep throat. Cutting capacity, 27 by 12½-in; table, 18 by 24 in., tilts 45 degrees right, ten degrees left. Blades, ⅛ to 1 in. wide. Blade speeds, 550, 1050, 1750 and 2700 fpm. Sealed ball-bearing saw guides. T. Farrell Machine Co., Berkeley, Calif.

FLEXIBLE SHAFT POWER UNIT. Countershaft vertically adjusted by leadscrew with knob control. Step pulley on motor shaft for speed adjustment. Hinged belt guard is shock mounted. Nonravel flexible shaft of cold-worked music wire operates within reinforced rubber casing. Elliott Mfg. Co., Binghamton, N. Y.

Materials Handling

MOBILE CRANE. For lifting and carrying loads up to seven tons. Three-way positive electric control for pin-point spotting, lifting and placing of load. Motors are fed by high-capacity generator driven by engine of tractor which pulls crane. Positive steering by electric motor unit. Positive braking at any height by automatic slip-proof brakes on electric motors. Road speeds to 28 mph. R. G. LeTourneau, Inc., Longview, Texas.

SKID TRUCK. Loads lifted by foot-pump powered hydraulic cylinder. Dead-man control. Double-position brake applied by raising or lowering guide handle. Automatic Transportation Co., Chicago.

ELEVATING PLATFORM. Hydraulic. For positioning work during assembly operations. Capacity, 500 lb. Elevation range, 4 to 30 inches. Powered by foot pump. Metal guards over lifting mechanism and pump-release pedal. Lyon-Raymond Corp., Greene, N. Y.

COUNTING AND WEIGHING SCALES. Mounted on wheels and four-foot high legs. Hydraulic lift swings load clear of floor; direct weight or count readings are taken from indicating head. Capacity, 1000 lb. National Scale Co., Springfield, Mass.

FORK TRUCK. Pneumatic-tired; 6000-lb capacity. Frame, welded heavy rolled steel. Engine, 6-cylinder, 50 hp; pivoted steering; full floating drive axle; dual drive wheels; dou-

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MASTER HIGH STRESSES IN HYDRAULIC PRESSES

Extra strength, pressure-tightness and wear-resistance characterize major castings in this "Hydrolair" press . . .

Moreover, these properties may be secured whenever needed in cast parts by producing them in nickel alloy irons.

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Along with essential strength, this type of nickel-chromium cast iron provides a dense, close-grained structure that remains free from leaks or pressure losses even though hydraulic stresses run high.

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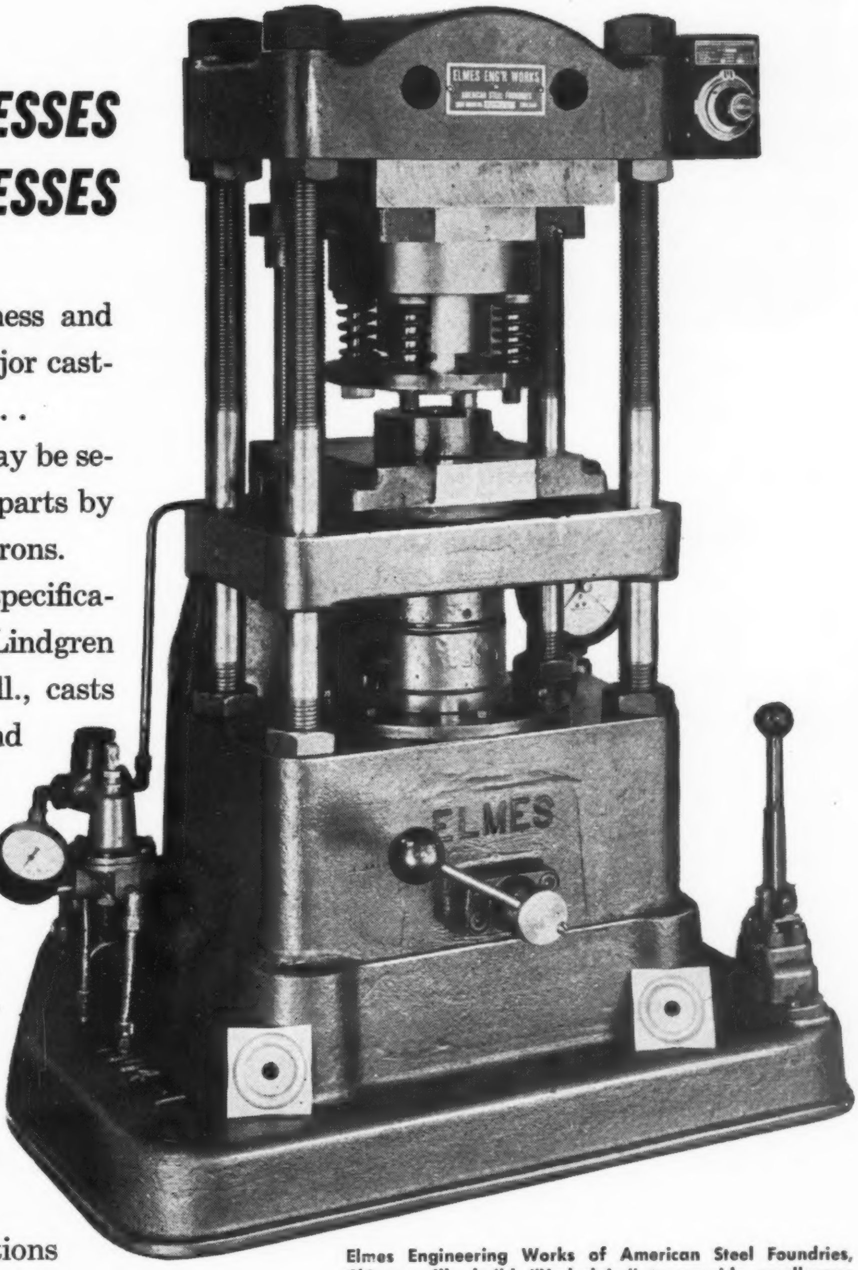

Elmes Engineering Works of American Steel Foundries, Chicago, Ill., build "Hydrolairs" to provide small-press users with equipment for fast, economical operation. Floor and bench type models of 20, 30 and 50 ton capacity are available.

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ble-reduction steering mechanism. Lift, 112 inches. Clark Equipment Co., Industrial Truck Div., Battle Creek, Mich.

Metalworking

DIE CASTING MACHINE. Hydraulic. For zinc, tin or lead production. Shot capacity, 32 oz.; top speed, 720 shots per hour. Casting cycle automatic. Light Metal Machinery, Inc., Cleveland.

MILLING MACHINE. Milling feeds and rapid traverse by hydraulic power. Saddle slides vertically on column. Oiling is by power pumps or splash system. A 3-hp hydraulic unit mounted on column provides continuously variable feeds from 1 to 15 in. per minute and power traverse of 90 in. per minute to spindle head slide, spindle head unit on column and column unit on runway. The Cincinnati Gilbert Machine Tool Co., Cincinnati 23.

MILLING MACHINES. Eighteen different dial types. Speed and feed changes controlled by single two-position lever. Built-in spindle-speed calculator. Vertical heads are hydraulically counterbalanced; built-in vibration damping units; lubrication by a pump and splash system. The Cincinnati Milling Machine Co., Cincinnati 9, O.

AUTOMATIC SCREW MACHINE. Six-spindle. Capacity, 2¼-in. Cross-slide cams within cross-slide mountings; chip conveyor; interchangeable tool holders. Stock feed-out length adjusted without changing cams. New Britain-Gridley Machine Div., The New Britain Machine Co., New Britain, Conn.

PORTABLE DRILLER AND TAPPER. For machining holes in extremely large units. Controlled from portable pushbutton panel. Drill head swivels 360 degrees in one plane, 180 degrees in other. In addition, head and rail unit revolves 360 degrees around and is vertically adjustable on machine column. Kaukauna Machine Corp., Kaukauna, Wis.

AUTOMATIC BRUSHING MACHINE. Three brushing stages clean steel-backed surface of strip used in thin-walled bearings. Each stage powered by 7½-hp electric motor. Air-pressure arrangement maintains constant pressure on metal back-up plate. Federal Mogul Corp., Detroit.

DRILLERS AND TAPPERS. Multi-spindle, adjustable. Electrically controlled hydraulic feeds. Leadscrew-adjustable knee-type work tables with wide coolant channels draining to machine bases. Heavy box-section columns; close-grain cast iron ways. Heads counterbalanced. Spin-

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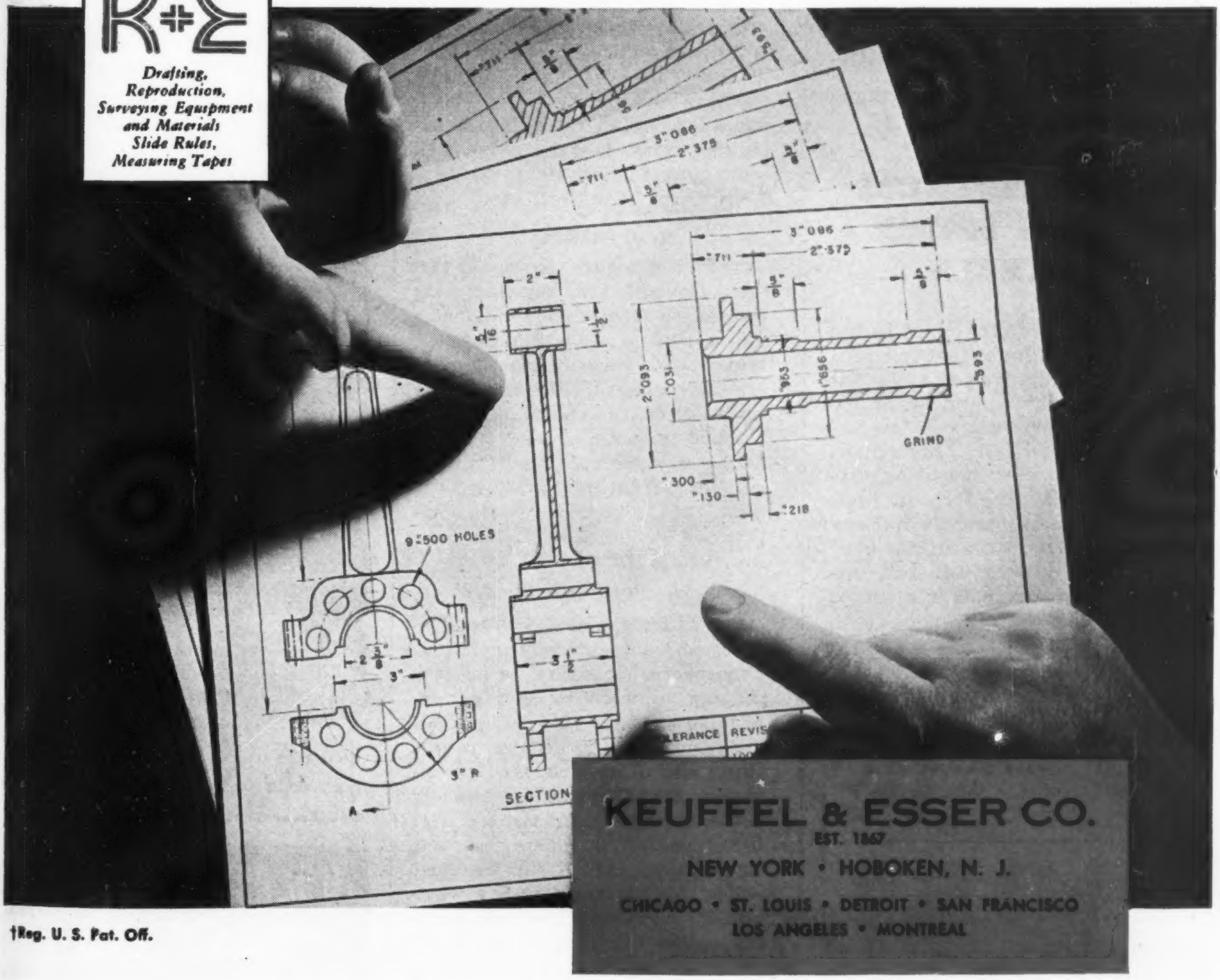

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dles driven through universal joints, can be located in any position within area of head. National Automatic Tool Co., Richmond, Ind.

Packaging

PACKAGING MACHINE. Automatic. Packages rock wool insulation in paper bags. Material is fed onto two alternate conveyors mounted on individual weighing mechanisms. Hoppers have air-operated duck bills which open and hold bags for filling. Pneumatically operated ram compresses rock wool in bags. Electrical controls in dust-proof housing. Union Bag & Paper Corp., New York.

Photographic

FILM SPLICER. Combination 8 and 16 mm. Electrical element in base heats shear blades, shortening cement-setting time. Provision made for scraping emulsion from both film ends. Gage block sets scraper blades. Base and operating arms are cast aluminum. Shear blades are hardened, ground stainless steel. Bell & Howell Co., Chicago 45.

Printing

PRINTING PRESS. Sheet cutoff, $8\frac{1}{2}$-in.; max. width paper roll, 14 in. Prints two colors on one side or one color on both sides of web; imprints, numbers and perforates in single operation. Prints up to 30,000 accurately cut sheets per hour in multi-color. Imperial Lithograph Press Corp., New York 18.

Road Building

DOZER. 25-ton, 300 hp. Top speed 13.6 mph forward and reverse. Constant-mesh transmission eliminates gear shifting. Steering clutches, brakes and transmission clutches are air actuated. Electrically operated blade control. Battery charged from a-c generator, eliminating d-c generator and voltage regulator. Four 24.00 by 29 tapered bead tires. Shipping weight, approx. 50,700 lb. R. G. LeTourneau Inc., Peoria, Ill.

Testing

HUMIDITY SIMULATION UNIT. Produces and automatically maintains atmospheric humidity conditions ranging from 20 to 95 per cent, from 35 to 175 F (dry bulb). Used in testing radio condensers, paints, paper containers, soil, seed germination, etc. Operates on 110-volt, 60-cycle, single-phase current. Wet bulb control; humidity reservoir water level maintained by float valves. Air movers provide circulation within stainless steel test space. Bowser, Inc., Refrigeration Div., Terryville, Conn.